NASA-CR-199805

IN-18-CR

6506
P- 103

AC Engineering/SAIC Joint Annual Progress Report
December 10, 1995

1. *Contract Name:* Development and Application of Contamination Technology for MSFC Managed Space Systems

2. *Contract Nr:* NAS8-39244

3. *Reporting period:* December 10, 1994 to December 10, 1995.

4. *Technical Progress:* This is the fourth annual report for this contract. HD-2 grease coating spots purposely applied to an RSRM nose inlet housing (7075-T73 aluminum) were accurately located, identified and quantified with the UVF laser contamination detection system. The experiment successfully demonstrated the potential of the analysis technique for flight hardware.

Studies were conducted to evaluate Near Infrared Optical Fiber Spectrometry (NIR) and OSEE II as methods for quantifying tape adhesive residue levels on metallic RSRM surfaces. Residue level estimates based on NIR measurements compared favorably to gravimetric results, but estimates based on OSEE II analyses were less precise since several of the adhesives were photoemissive.

A series of environmental exposure experiments was performed to determine the relative effects of temperature and humidity (RH) on the oxidation rate of grit blasted LiAl. Based on OSEE II analyses, oxidation rates over five-day test periods were predominantly controlled by RH conditions.

Tests were conducted with the OSEE III system and 6" sensors to determine how scan speed, scan mode, sensor dwell time, sensor stand-off distance, argon gas purging of the sensor/substrate gap region, and grit blast angle effected the responses of grit blasted D6AC steel panels.

Efforts during the report period included the following activities:

1. Successfully identified, located and quantified HD-2 contamination spots on an RSRM nose inlet housing with the UVF laser detection system.

2. Evaluated NIR and OSEE II as methods for quantifying tape adhesive residue levels on metallic RSRM surfaces.

3. Performed environmental exposure tests to determine the relative effects of temperature and humidity on the oxidation rate of grit blasted LiAl.

4. Continued evaluation of the OSEE III system and 6" sensors by quantifying the impacts of scanning parameters such as speed, stand-off distance and argon gas purging on the response of D6AC steel.

UVF Eximer Laser Contamination Detection System; Analysis of RSRM Nozzle Contamination Test Articles

Contamination test articles prepared from components of the RSRM nozzle were scanned with a UVF eximer laser system developed by Physical Sciences, Inc. (PSI). A nose inlet housing (7075-T73 aluminum), throat housing (D6AC steel), and forward nose ring (carbon/glass phenolics) coated with various levels of hydrocarbon and silicone oils were examined to see how accurately the system would detect, identify and quantify surface contamination. The coatings simulated bond affecting materials typically found in RSRM component manufacturing areas, for example mold releases and preservative greases.

Initial Test Results

Table I summarizes the initial test results obtained by PSI, along with types, levels and locations of contaminants applied to the RSRM nozzle components. Results are also summarized in Figures I-III, which show 360° surface maps of coatings applied versus those detected by the UVF system.

Test article contamination types, levels and locations were not provided to PSI prior to testing of the UVF system. The three contaminants were Conoco HD-2 grease, paraffin wax and CRC Silicone mold release. Coating levels ranged from 1 mg/ft^2 to 20 mg/ft^2; coating patterns were 6" X 6" on the metallic pieces, and 4" X 6" on the glass phenolic. There was confusion regarding analysis of the forward nose ring, because PSI personnel expected that the carbon phenolic section would be contaminated, not the glass phenolic section. Therefore, glass phenolic contamination step plates also had to be examined so the instrument could be calibrated for this substrate.

Nose Inlet Housing: 7075 T-73 Aluminum

Three levels of HD-2 grease were applied to the nose inlet housing, and all three were detected. However, two of the three coatings were quantified at levels significantly lower than were actually applied. A 5 mg/ft^2 spot was measured as 1 mg/ft^2, and a 20 mg/ft^2 coating was quantified as 2 mg/ft^2.

Two of four paraffin contamination spots were located. A 13 mg/ft^2 coating was quantified as 9 mg/ft^2, but the accuracy of the second measurement could not be determined since the true coverage level was questionable. Paraffin coatings of 2.9 mg/ft^2 and 7.5 mg/ft^2 were not found.

Only one of three CRC Silicone coatings were detected (a 9 mg/ft^2 spot was estimated to be 5.2 mg/ft^2), and an additional silicone signal (4.2 mg/ft^2) was reported in a region where the mold release had not been intentionally applied (275°, 17" down from top of part). Since no greases or oils were visible in this area, which was near the bottom of the test article, it was believed that the erroneous signal may have been caused by contamination on the robot turntable.

Throat Housing: D6AC Steel

All three levels of HD-2 grease were detected on the steel throat housing, but only the lowest coating level was accurately quantified. A 2 mg/ft^2 spot was measured as 1.8 mg/ft^2, but 8.4 and 14 mg/ft^2 levels were estimated to be 2.5 and 3 mg/ft^2, respectively. An additional HD-2 signal reported at 110° may have been misidentified CRC Silicone that was applied at 0.5 mg/ft^2 in this region.

Only one of four paraffin coatings were detected (a 16 mg/ft^2 level was measured as 24 mg/ft^2), and none of the three CRC Silicone contaminants (up to 10 mg/ft^2) were found.

Forward Nose Ring: Glass Phenolic Section

Although CRC Silicone was not detected on glass phenolic, quantification results for the hydrocarbon contaminants were significantly more accurate with this substrate than with the metallic test articles. Three levels each of paraffin and HD-2 grease were applied to the nose ring, and with only one exception (a 17 mg/ft^2 paraffin coating was quantified as 41 mg/ft^2) all were found and measured to within an acceptable margin of error.

Conclusions

Differences between contaminant locations reported by PSI and the true locations were considered to be insignificant, and were probably due to slight misalignments of the parts relative to the turntable "0" line.

True silicones would not be expected to fluoresce under UV light of the wavelength generated by the Lextra laser. Although CRC Silicone had the potential to be detected since it contained CH_x functionalities, it was expected that the oil might be misidentified as a hydrocarbon. This was apparently the case with the 0.5 mg/ft^2 CRC Silicone spot identified as HD-2 grease on D6AC steel.

PSI personnel conjectured that CRC Silicone was not detectable on glass phenolic because it had been absorbed into the substrate. Emission intensities from the step-plate calibration standard were essentially constant (which contained 5 levels of CRC Silicone contamination), and were approximately equal to that of clean glass phenolic. However, while these observations were consistent with absorption of the coating into the substrate, the same step plate was used to successfully develop a predictive model for the NIR system. A more likely explanation for failure of the UVF system to find CRC Silicone was that, due to the fairly low levels applied to the test article, the concentration of hydrocarbon functionality was not high enough to generate measurable fluorescence signals.

When the metallic test articles were analyzed, significant fluorescence signals were generated by the curtains surrounding the robot test cell, and by contamination on the turntable. These signals were mathematically removed by

PSI during data analysis, which resulted in losses of information from the top 4" of the parts. While this would possibly explain the missed coatings near the tops of the components, or perhaps some of the erroneous quantification values, some results were still difficult to understand. For example, an 8 mg/ft^2 paraffin coating 10-16" down from the top of the 7075 aluminum part was not detected, while a 13 mg/ft^2 paraffin coating applied 0-6" down from the top of the same part was correctly identified and closely measured as 9 mg/ft^2.

Quantification results were significantly more accurate with the forward nose ring than with the metallic test articles. The nose ring was scanned at an angle that did not allow the laser beam to strike the background curtains, and aluminum barriers were placed on the turntable around the outer edges of the test article. It was believed that eliminating fluorescence signals from the curtains and turntable might improve instrument sensitivity to contaminants on the metallic test articles, therefore the turntable and background areas were covered with a non-fluorescing cloth material.

Analyses of Witness Panels and Foils

FT-IR Analyses of Aluminum Foil Witness Samples

Aluminum foil witness samples sprayed along with the test articles and used to gravimetrically determine coating levels were examined with the FT-IR microscope; results are summarized in Table II. The data were not directly comparable to results obtained from contamination standards prepared with grit blasted panels, because the smoother foils produced significantly higher reflectance values. However, there were significant peak height differences between the highest and lowest coating levels examined, which confirmed that the coating level trends determined gravimetrically were correct.

FT-IR Analyses of Metallic Witness Panels

Table III summarizes results from FT-IR analyses of metallic witness panels sprayed along with the RSRM nozzle parts. The panels were examined both prior to and following the PSI laser demonstration; the purpose was to determine whether coating levels had changed (due to diffusion or volatilization) during the course of the laser tests.

In general, the pre/post laser test peak heights were not significantly different, which indicated that the coatings were stable over the time period required to perform the UVF analyses. The one exception was the change observed for the Si-C stretch peak of CRC Silicone (1260 cm^{-1}) on the throat housing. Initial Si-C peak height measurements averaged 0.021, and post laser test peak heights averaged 0.010. However, the -CH stretch peak at 2960 cm^{-1} remained unchanged (avg. 0.004 for pre/post test measurements). The region of the IR spectrum containing the Si-C peak was difficult to flatten using baseline correction techniques, which made peak height measurements difficult. The region containing the -CH peaks was more easily examined, and it was therefore believed that these data more accurate.

The pre/post laser test FT-IR measurements from the witness panels were compared to peak height averages obtained from multiple scans of contamination step plate standards (Table IV). For 7075-T73 aluminum, multiple scans of contamination standards containing HD-2 grease, CRC Silicone or paraffin wax exhibited 13-25% variations in average peak height values for the same coating level. Differences between pre/post laser test peak height measurements averaged 5-10% for the aluminum witness panels, therefore results were well within a range expected for identical coating levels.

Multiple scans of D6AC step plate contamination standards indicated that average peak height variations of 16-30% could be expected for a given contamination coating level. The pre/post laser test FT-IR measurements for D6AC witness panels containing CRC Silicone or paraffin were 0% and 11%, respectively, which confirmed that the coating levels had not changed. HD-2 grease exhibited a 41% decrease in average peak heights after the PSI demonstration, which was a significant change based on results from analysis of the contamination standards. However, since no other witness panels exhibited such dramatic changes in FT-IR responses, and since the throat housing did not experience extraordinary environmental conditions that might have affected the coatings on this part to a greater extent than coatings on the other test articles, the results were considered to be anomalous. Several analyses were made of the HD-2 witness panel following the PSI tests, and the average peak height values were consistent at around 0.01 log 1/R. It was therefore believed that the pre-test peak height average was incorrect; perhaps an inadequate number of data points were obtained, which resulted in an erroneously high initial average.

NIR Analyses of Glass Phenolic Witness Panels

NIR optical fiber spectrometry was used to monitor the glass phenolic witness panels. First, a calibration set of NIR data was developed using six known levels of CRC Silicone, HD-2 grease or paraffin contamination on glass phenolic plates. The calibration data were then used to predict the levels of contamination on witness panels contaminated in parallel to the RSRM forward nose ring (Table V).

The initial and final predictions for HD-2 grease and CRC Silicone were consistent to within a range expected based on experimental error, and were very to close to coverage levels determined gravimetrically. The paraffin coating also remained unchanged, but gravimetric data were not obtained for this contaminant.

New Calibration Data for HD-2 Grease on 7075-T73 Aluminum

For several reasons, it was believed that initial results from UVF laser analyses of the RSRM nozzle segments were not optimized. First, fluorescence signals from the robot turntable and background curtains could have masked signals from contamination on the nozzle parts. Second, the UVF system had been calibrated at the PSI laboratories in a configuration that did not require the laser beam to be directed toward the sample using mirrors, as was being done at MSFC.

Fluorescence signals from the robot turntable and background curtains were eliminated by covering them with a non-fluorescing black cloth. Then, aluminum/HD-2 contamination standards were analyzed to develop a new calibration curve for HD-2 grease. The standards were grit blasted 6" x 6" panels coated with 3-22 mg/ft^2 levels of HD-2 grease, which were similar to grease levels on the nose inlet housing test article. As shown in Figure IV and Table VI, good correlation was observed between UVF signals and HD-2 coating levels.

The RSRM nose inlet housing contamination test article was examined using the new MSFC calibration data, but fluorescence signals from the standards and test article did not correlate. A 20 mg/ft^2 calibration standard registered approximately 9000 counts, while a supposed 20 mg/ft^2 coating on the test article measured only 2500-3000 counts. Likewise, a 5 mg/ft^2 standard measured 5000 counts, while an "equivalent" spot on the nozzle part showed only 500-700 counts.

Based on these results, HD-2 coating levels on the aluminum nozzle part were considered suspect. Therefore, two additional HD-2 spots were applied to the test article for comparison to the calibration standards. As shown in Figure V, results from analyses of these new spots compared favorably to fluorescence signals obtained from calibration standards with similar coating levels.

Examination of New HD-2 Grease Spots on Nose Inlet Housing

Because of the encouraging results with the two new HD-2 grease spots, the decision was made to conduct a "blind" test where the nose inlet housing would be analyzed for additional HD-2 coatings placed in positions and at levels unknown to the instrument operators. Personnel responsible for applying the coatings did not participate in the analyses, and did not reveal the number of new spots, their levels or locations until after tests were completed.

The nose inlet housing was scanned in 20-degree increments, with 25 pulses per image. Initially, the detector was held in one vertical position; although the entire housing surface could be observed on the computer screen, data was lost from the upper and lower 3-4" of the test article when image clipping was performed to remove noise. Analysis of the part was therefore repeated using vertical positions of 36" and 45" from the camera center to the floor.

Figure VI shows results from the upper 7"-17" of the nose inlet housing. The contour lines were plotted such that the area inside contour line number #1 to the next contour line included coating levels greater than or equal to level #1, but less than level #2. Estimates of HD-2 levels from 1-20 mg/ft^2 were used to produce the plot in Figure VI, then each spot was examined individually with a narrower range of contour levels.

Table VII and Figure VII summarize the results. Seven new HD-2 coating spots were applied to the nose inlet housing, and all seven were detected and accurately located. With the exception of the contamination spot located at 335° and 6" from the top of the housing, predicted coating levels based on UVF analyses were close to the gravimetrically determined levels. The coating at 335° was gravimetrically determined to be 20-22 mg/ft^2, but the UVF estimated level was only 7-9 mg/ft^2. Since the other coatings were accurately quantified, it was believed that gravimetric results for the 335° spot were in error.

Only two of the three original HD-2 coatings were detected. Although a 1.6 mg/ft^2 coating (gravimetric level) was accurately quantified as 1-1.5 mg/ft^2, a 20 mg/ft^2 spot was estimated to be only 1-2 mg/ft^2. The results were surprising since the coating was easily visible to the unaided eye, and it appeared to be more concentrated than the newly applied 2-3 mg/ft^2 spots. Approximately 18 mg/ft^2 of residue were collected from an NVR analysis of the coating, and FT-IR microscope analysis revealed it to be primarily HD-2 grease. However, a significant quantity of unidentified material was also collected, so it was therefore believed that the UVF response had been reduced by a layer of dirt that had adhered to the HD-2 grease. It was expected that the undetected 5 mg/ft^2 HD-2 coating was also "contaminated" with a layer of dirt.

Conclusions

The analyses of the new coatings demonstrated that the UVF system could accurately identify and quantify HD-2 grease contamination on the RSRM nose inlet housing. All of the HD-2 coatings were accurately located, and coating levels based on UVF responses were typically within several mg/ft^2 of the gravimetrically determined levels

Although the original HD-2 grease coatings on the nose inlet housing should be acceptable for contamination identification testing, they were found to be unreliable for quantification measurements. Precautions were taken to protect the test article after coatings were applied, but the HD-2 grease spots, and presumably the CRC Silicone and paraffin coatings as well, were discovered to be covered with dirt. It was believed that the coatings became contaminated during the application process, which occurred out-of-doors.

Plans for continued evaluation of the UVF system include examining the CRC Silicone and paraffin coating spots on the nose inlet housing, and examining the other test articles. If the original coating spots exhibit significantly lower fluorescence signals than contamination standards, new coatings will be applied to the nozzle segments.

Tape Residue Studies with NIR Optical Fiber Spectrometry

Studies were conducted to evaluate the NIR optical fiber analysis technique as a method for quantifying tape adhesive residue levels on RSRM surfaces after masking operations. D6AC steel and 7075-T73 aluminum panels were covered with four tapes commonly used in RSRM processing operations: paint masking tape, grit blast masking tape, bonding application tape, and yellow vinyl tape. The taped panels were held at ambient temperature for 10 days, after which the tapes were removed and the panel surfaces analyzed with the NIR integrating sphere. The test articles were then immersed in methyl chloroform to remove the adhesives, which were collected and quantified. To determine if the adhesives had been completely removed, additional NIR data were obtained after the cleaning process. OSEE II, FT-IR and gravimetric data were also obtained for comparison with the NIR results. The flow diagram in Figure VIII outlines the test procedure.

Gravimetric Results

Table VIII summarizes gravimetric results for the tape residue experiments. For both substrate sets, approximately 8-14 mg/ft^2 levels of tape adhesive residues were recovered for all except grit blast tape. Only 2-3 mg/ft^2 were collected for grit blast tape, which suggested either that small quantities of tape residue were present on the panel, or that methyl chloroform was not an efficient solvent for this adhesive.

OSEE II Results

In general, OSEE results for the 7075-T73 aluminum samples followed the expected trends (Table IX). The plates averaged 1966-1980 centivolts (cV) prior to tape application, and 1452-1668 cV after tape removal. A baseline panel without tape exhibited only a 143 cV drop during this time period, therefore response changes for the taped panels were considered to be significant. Excluding panel 52, which contained the yellow vinyl tape, OSEE signals increased to within 5-7 percent of their baseline values after cleaning with methyl chloroform. It was unclear why the OSEE signal for panel 52 did not also increase, since approximately 9 mg/ft^2 of residue were isolated after cleaning (Table VIII).

Results with the D6AC steel panels were not as consistent as those with aluminum. The steel panels averaged 667-752 cV before tape application, and 426-799 cV after tapes were removed. Interestingly, the panel containing yellow vinyl tape (panel 34) exhibited an *increase* in response from 713 cV to 799 cV after tape removal, which indicated that the adhesive might be photoemissive. The plate with grit blast tape showed a significant signal drop (261 cV) compared to the baseline (90 cV), while panels with masking and bonding tape were equivalent to the baseline. OSEE responses for the D6AC steel test articles did not increase after immersion in methyl chloroform, even though measurable amount of adhesives were obtained by the cleaning process (Table VIII).

Table X and Figures IX-X summarize OSEE II analysis results from steel and aluminum calibration standards used to support these studies. The standards were examined to develop OSEE II response trends for the four adhesives, to determine if OSEE analysis could be used to predict coating levels on test panels after tapes were removed, and to develop predictive models for the NIR.

Figure IX shows plots of percent initial OSEE II signals versus coating levels for the adhesives on aluminum. Grit blast tape adhesive had the most pronounced effect on OSEE responses, and produced a 50% reduction in signal at approximately 3 mg/ft^2. Vinyl tape adhesive and bonding tape adhesive had more moderate effects on OSEE response, and required approximately 20 mg/ft^2 to produce 50% signal reductions.

Figure X shows plots of percent initial OSEE II signals versus coating levels for the adhesives on D6AC steel. OSEE responses for panels coated with vinyl tape adhesive remained flat up to 20 mg/ft^2, and responses for bonding tape adhesive increased relative to the baseline. These data supported the theory that vinyl tape adhesive was photoemissive, and suggested that bonding tape adhesive was emissive as well. Grit blast tape adhesive also produced an increase in OSEE II signals as coating levels increased from 5-15 mg/ft^2. A second set of standards prepared with these adhesives produced the same results for vinyl and bonding tape adhesives, but panels coated with grit blast tape adhesive showed consistent decreases in responses with higher coating levels (Figure XI).

If vinyl and bonding tape adhesives were photoemissive on D6AC steel, one would also expect them to be emissive on aluminum. It was unclear why results were different for the two substrates, but it was possibly due to the higher initial responses for aluminum. Baseline readings averaged 1660-1961 cV for the aluminum panels, and averaged 448-547 cV for the D6AC steel plates. Results from an additional set of OSEE tests where the tapes were applied to freshly grit blasted D6AC steel panels for 10 days (a repeat of the original experiment) are summarized in Table XI. The baseline panel exhibited a 20% drop in signal, from 746 cV to 595 cV. The panel with yellow vinyl tape showed only an 8% drop in signal, and the response after tape was removed (778 cV) was similar to that of the original test (799 cV). The panel with bonding tape dropped by 14%, which was also lower than the baseline and similar to the response observed in the original experiment. The conclusions were that the higher initial OSEE signals for the second experiment did impact the results, but yellow vinyl and bonding tape adhesive residues still appeared to be photoemissive.

One purpose of these analyses was to determine whether OSEE II could be used to predict adhesive coating levels on the test articles after tapes were removed. In light of the results, estimates would have to be considered questionable. Nevertheless, predictions were made for comparison to results obtained by the other analysis techniques. As shown in Tables XII-XIII, the predictions did not agree with estimated coating levels based on NIR or gravimetric data.

Summary

Table VII summarizes the OSEE II, FT-IR, gravimetric and NIR results. Based on NIR analysis, estimated adhesive coating levels were 8-19 mg/ft^2 immediately after tapes were removed. NIR measurements performed after the plates were washed in methyl chloroform indicated that 6-14 mg/ft^2 of the residues were removed; none of the plates were completely cleaned. The NIR estimates agreed reasonably well with the gravimetric results, and were typically within 2-3 mg/ft^2. The major exception was vinyl tape adhesive on D6AC steel; NIR analysis predicted that 8 mg/ft^2 was removed by the methyl chloroform wash, while 14 mg/ft^2 were measured gravimetrically.

OSEE II Studies with Grit Blasted LiAl

A series of experiments was performed to evaluate the effects of temperature and relative humidity (RH) conditions on the oxidation rate of grit blasted LiAl. OSEE II and NIR data were collected from LiAl panels as they were exposed to a range of environmental conditions for five-day time periods. Target temperature extremes were 60-90°F, and target RH extremes were 20-70%. Actual temperatures were within ± 2°F of the targets, but RH conditions varied by as much as ± 12%. The environmental chamber typically achieved equilibrium conditions within 10 minutes after test panels were inserted; the one exception was the test at 60°F/50% RH, which required 60 minutes.

Figures XII-XIV and Table XIV summarize the OSEE II results. Initial OSEE responses averaged from 1543 cV (90°F/70% RH) to 1992 cV (60°F/70% RH), and final responses averaged from 242 cV (90°F/20% RH) to 735 cV (60°F/70% RH). Plots of average OSEE II responses versus time for six of the nine experiments exhibited interesting response changes beginning approximately 60-120 minutes into the environmental exposure cycles. OSEE II signals decreased rapidly upon initiation of the experiments, but after 60-120 minutes the responses stabilized or increased. The data suggested that significant changes in oxidation state were occurring during these time periods, but the chemistry of the changes could not be determined from the OSEE data. It will be interesting to see if more detail will be provided from NIR measurements that were also obtained during the environmental exposure tests.

Statistical Analyses of OSEE II Results

Table XV summarizes the OSEE II data used to establish the effects of temperature and relative humidity on the oxidation rate of grit blasted LiAl. The three responses evaluated were line slope (cV/min.), y-intercept (cV), and overall change in OSEE II signal (Δ-OSEE, cV). The line slope and y-intercept values were obtained from linear regression analyses (Excel 4.0) of the data plots shown in Figures XII-XIV. Although the curves were not strictly linear, the regression analyses provided average response changes over the five-day test periods. An example of the regression plots is shown in Figure XV (60°F/20% RH), and complete results are provided in Table XVI.

Design-Expert software (Version 4.0.2) was used to perform the statistical analyses. The design parameters were as follows:

a) Study Type: Response Surface, 2 Factors, Rotatable

b) Response Surface Design Type: Central Composite, full

c) Number of Experiment Blocks: 1

d) Factors: Temperature, Relative Humidity

Figures XVI-XVII show perturbation and 3-D contour plots of the analysis results. All three responses were predominantly controlled by RH conditions; this was especially true for the y-intercepts, which did not vary significantly with changes in temperature. Interestingly, slope and y-intercept responses were directly proportional to temperature and inversely proportional to RH, while the reverse was true for Δ-OSEE. Additional data analysis results, including ANOVA calculations, standard error plots, and normal probability plots can be found in Appendix A.

Based on the analysis results, mathematical models were developed for predicting slope, y-intercept and Δ-OSEE responses as functions of temperature and RH conditions:

Slope (cV/min.) = -0.03276 + 1.77E-4(Temp) - 2.87E-4(RH)

Y-Intercept (cV) = 1846 + 0.729(Temp) - 6.90(RH)

Δ-OSEE (cV) = 467 - 5.66(Temp) + 8.77(RH)

A summary of experimental responses versus predicted responses is shown in Table XVII. Predicted values were generally comparable to the experimental results, but there were significant deviations. The primary sources of error which affected development of the models were linear regression analyses of non-linear data (correlation coefficients ranged from 0.5-0.9), differences in initial OSEE II responses arising from variations in grit blast angles, and changes in UV lamp output with time.

Evaluation of the OSEE III System and 6" Sensors

Evaluation of the OSEE III system and 6" sensors was continued during 1995. Significant differences from the OSEE II system included argon gas purging of the sensor/substrate gap region, a 6" scan area, and the option of continuous or discrete scanning modes. Progress this year included development of a procedure for calibrating the six data channels of the 6" sensor; evaluating the effects of scan speed, scan mode, sensor dwell time, stand-off distance, grit blast angle, argon gas purging and HD-2 grease contamination on the responses of D6AC steel; and development of a data base of responses for D6AC steel over fourteen days after grit blasting.

Development of Sensor Calibration Procedure

The OSEE III 6" sensor contains six data channels which must be independently adjusted for gain. It was desirable that the six channels respond equivalently when materials were analyzed, therefore it was necessary that a calibration procedure be developed. The OSEE III Operation Manual ("Instruction Manual For The Operation Of OSEE Third Generation", Odell Huddleston, Thiokol Corp., and Daniel Perey, NASA-Langley) recommended that the gain potentiometers be adjusted as the sensor was positioned at the desired stand-off distance over a calibration standard. However, the signal responses fluctuated rapidly when the sensor was held at 1/4" from a passivated D6AC steel panel, which made the calibration procedure extremely difficult. Voltage readings for each channel varied from 0.5 V to 1.2 V, which resulted in a 70-100 counts difference in responses across the six channels.

The decision was made to continue using D6AC steel as a calibration standard, but to evaluate channel outputs during scanning. Gain potentiometers were initially set to their mid-points, about seven revolutions from the limits. A freshly grit blasted D6AC panel was scanned every 5-7 minutes for period of 30 total minutes, during which channels 1-2 and 4-6 were slowly adjusted to bring them into agreement with channel 3. After each scan the output for every channel was studied to determine if the gain needed to be adjusted higher or lower. Adjustments were made, then the panel was analyzed again. Figure XVIII shows plots of OSEE III responses versus time for grit blasted D6AC steel panels when the sensor was calibrated either by holding it steady over the calibration standard, or when gain adjustments were made during scanning of the standard. Responses across the six channels varied by 70-100 counts when the recommended calibration procedure was used, but varied by only 17-40 counts when gains were adjusted during scanning. Following the final gain adjustments, five additional D6AC steel panels were analyzed for periods of 2 hours after grit blasting. As the data in Table XVIII show, differences in signal outputs across the six channels remained low at about 6-23 counts.

Sensor Stand-Off Distance

To establish the effects of sensor stand-off distance, measurements were taken from a passivated D6AC panel at distances ranging from 0.2-0.4 inches, in 0.01 inch increments. A passivated D6AC panel was selected for these experiments so that changes in the oxidation state of the surface would be minimal over the period of time required to perform the analyses. The panel had been grit blasted 5 days earlier, and measured 480 cV on the OSEE II.

Results are summarized in Table XIX and Figure XIX. OSEE responses were nearly linear over this range of stand-off distances, but several distinct changes in slope were observed. Responses dropped consistently from 110 to 80 counts as the gap was increased from 0.2 to 0.25 inches, were nearly flat from 0.25 to 0.29 inches, and decreased again from 0.29 to 0.4 inches.

Based on these results, 0.25-0.29 inches were the optimum stand-off distances for the OSEE III 6" sensor. Since the response curve was flat in this region, slight deviations in stand-off distance would not be expected to significantly impact OSEE responses.

Continuous Versus Discrete Scanning Modes

Table XX and Figure XX summarize results from analyses of grit blasted D6AC steel panels using the continuous or discrete scanning modes. Test panels were examined every 5-7 minutes with either one continuous scan, or in 5 discrete steps.

There were no significant differences in response trends when grit blasted D6AC steel was analyzed using the two scanning modes. Initial measurements averaged 346 counts with the continuous scanning mode, and averaged 330 counts with the discrete mode. Final responses obtained five hours after grit blasting were also equivalent, and averaged 181-184 counts. The plots overlapped for the duration of the test, which monitored the period of most rapid oxidation.

The experiment demonstrated that equivalent results could be obtained with discrete or continuous scanning modes. However, continuous scanning was considered to be more desirable since it was the quicker of the two methods.

Evaluation of Scan Speeds

Table XXI and Figure XXI summarize measurements obtained from grit blasted D6AC steel using scanning speeds from 1 to 4 inches per second, the current limits of the OSEE III system. A steel panel was analyzed every 6-10 minutes at each scan speed, for a period of 0-400 minutes after grit blasting.

Based on the results, scan speeds from 1-4 inches per second did not significantly impact OSEE III responses for D6AC steel. Initial and final signal averages were similar for all scan speeds, and plots of average responses versus time were equivalent for the four speed settings. The increase in responses from 330 and 400 minutes may have been due to alternating the instrument between Scanning and Standby modes (to conserve argon) during this time period.

Effect of Sensor Dwell Time

To help eliminate response variability caused by slight temperature and humidity fluctuations, the OSEE III system establishes an argon purged environment between the sensor and substrate. It was expected that a time delay between positioning the sensor over the substrate and acquisition of data might be required to develop a uniform purged environment, therefore a series of experiments were performed with sensor dwell times ranging from zero seconds to 10 seconds.

Figure XXII and Table XXII summarize results from analyses of D6AC steel using sensor dwell times of 0, 5 and 10 seconds. Plots of average OSEE III responses versus minutes from grit blast were similar for the three delay times, which suggested that a uniform argon environment was established almost immediately upon bringing the sensor to the proper stand-off distance. However, as shown in Figure XXIII and Table XXIII, the three methods resulted in significantly different initial responses from the test panel. Responses averaged 126 counts at zero-time with no sensor delay, and averaged 193-196 counts when the longer dwell times were employed. Responses for the 0-second delay scan gradually increased to the same level as the others, but approximately 2.0 cm of the panel were scanned before this occurred. Thus, although average responses were equivalent for the three dwell times, the 0-second delay was apparently not adequate to achieve a completely purged environment.

Based on these experiments, a delay time of 4-5 seconds was required to obtain an equilibrated argon environment between the sensor and substrate. Although the lower initial readings associated with a 0-second dwell time would not influence results when large areas are scanned, they would have an impact if the responses were a more statistically significant percentage of the data points collected.

Analysis of D6AC Steel with HD-2 Grease Contamination

Table XXIV and Figure XXIV summarize results from OSEE III analyses of D6AC steel panels coated with 0-160 mg/ft^2 levels of HD-2 grease. A 1 mg/ft^2 coating level produced a 15% decrease in average responses, from 214 counts to 185 counts. Signals continued to drop significantly as grease levels were increased from 1 to 15 mg/ft^2, at which point readings were 30% of the baseline value. The signals remained constant at approximately 50-60 counts with coating levels from 15 mg/ft^2 to 160 mg/ft^2.

Figure XXV shows a comparison of results from analyses of HD-2 coated steel panels with the OSEE II and OSEE III systems. Signal decreases were similar for the two systems over the range from 0-5 mg/ft^2, but began to deviate at levels above 5 mg/ft^2. OSEE II responses fell an additional 10% as coating levels were increased to 10 mg/ft^2, while the OSEE III signals dropped to 33% of the baseline. OSEE II responses decreased to 64% of the original value when 25 mg/ft^2 HD-2 had been applied, whereas the OSEE III signal average decreased by 80%.

Based on these analyses, the OSEE III system appeared to be more sensitive to HD-2 grease contamination over the range from 6 mg/ft^2 to 25 mg/ft^2. Response changes were similar for the two systems with HD-2 levels from 1-5 mg/ft^2, and from 50 mg/ft^2 and above. Comparison of levels from 25-50 mg/ft^2 was not performed.

Effect of Grit Blast Angle

Table XXV and Figures XXVI-XXVII summarize results from analyses of D6AC steel panels grit blasted at 20, 45 or 90-degree angles. Panels were monitored for periods of 14 days after grit blasting, and were held at laboratory conditions (typ. 75°F, 45% RH) for the duration of the tests.

As expected, grit blast angle had a significant impact on initial responses. Zero-time signals averaged 125, 151 and 195 counts for the 90, 45 and 20-degree blast angles, respectively. Response trends for panels grit blasted at 45 and 90-degree angles merged after 150 minutes, and were equivalent through 350 minutes. The 20-degree response curve remained significantly higher than the others during this time period.

Response trends were erratic for days 1-14. The curves were essentially flat, but signal variations of ±15-20 counts were not uncommon for the panels grit blasted at 20 and 45 degrees; variations of ± 10 counts were observed for the panel grit blasted at 90 degrees. Interestingly, responses from all three test panels during days 1-14 were typically higher than those obtained 6 hours after grit blasting; it was believed that variability was being introduced into the results by turning the instrument off (to conserve argon) in-between daily scans of the panels.

Argon Gas Purge Effects on Grit Blasted D6AC Steel

It was expected that use of an argon gas purge in the sensor/substrate gap region would increase output signals by eliminating oxidation resulting from exposure of the substrate to UV light in the presence of oxygen, and by removing moisture. To quantify the magnitude of the impact, a series of experiments were performed with grit blasted D6AC steel, passivated D6AC steel, and stainless steel test specimens.

Table XXVI and Figure XXVIII show plots of OSEE III responses for 2 grit blasted D6AC steel panels; one was monitored over time with argon purging to the gap region, and the other was monitored without argon purging. Significant differences in output signals were observed for the two analysis modes. Initial responses averaged 195 counts with argon purging, and averaged 107 counts without argon purging; the 88 count signal difference remained fairly constant over the course of the experiments. Figure XXIX shows plots of percent signal drops versus time for the two experiments. Signals decreased more rapidly for the specimen that did not receive argon purging during analyses, which indicated that use of the argon purge was helping retard oxidation build-up.

Figure XXX shows plots of OSEE III responses versus time for a single grit blasted D6AC steel panel scanned alternately with and without argon purging. Again, zero-time responses with argon (226 counts) were approximately twice has high as responses without argon (99 counts). Percent signal drops over time were initially more rapid without argon, but the trends merged after approximately 300 minutes.

As shown in Figure XXXI, percent signal decreases with intermittent argon purging (single panel experiment) were more modest than decreases with no argon purging, which again demonstrated that the argon was significantly reducing oxidation rates.

Summary of OSEE III Response Data for Grit Blasted D6AC Steel

Figures XXXII-XXXIII and Table XXVII summarize OSEE III Sensor #4 response data collected to date from grit blasted D6AC steel. The analyses were performed at laboratory ambient conditions (typically 75°F and 45% RH) with a scan speed of 2 in/sec, continuous scanning mode, 1/4" sensor stand-off distance , and 0-second dwell time.

Figure XXXII shows average response trends for the first two hours after grit blasting. Signals averaged 262 counts at zero time, 205 counts after thirty minutes, and 185 counts two hours after grit blasting. Also shown are predicted response limits for D6AC steel at ambient conditions; the curves outline the limits within 1 and 2 standard deviations of the average results.

Figure XXXIII shows plots of average responses through 14 days after grit blasting. Signal changes were moderate over this time period, and dropped from 160 counts after day one to 120 counts after day 14. Response trends over this time period were somewhat erratic in comparison to the two-hour results, but were expected to become better defined as additional results were included in the data base.

5. *Problems/Issues:* The z-axis controls for the gantry robot malfunctioned several times during the past 12 months, which impacted use and evaluation of the UVF analysis system.

6. *Plans:*

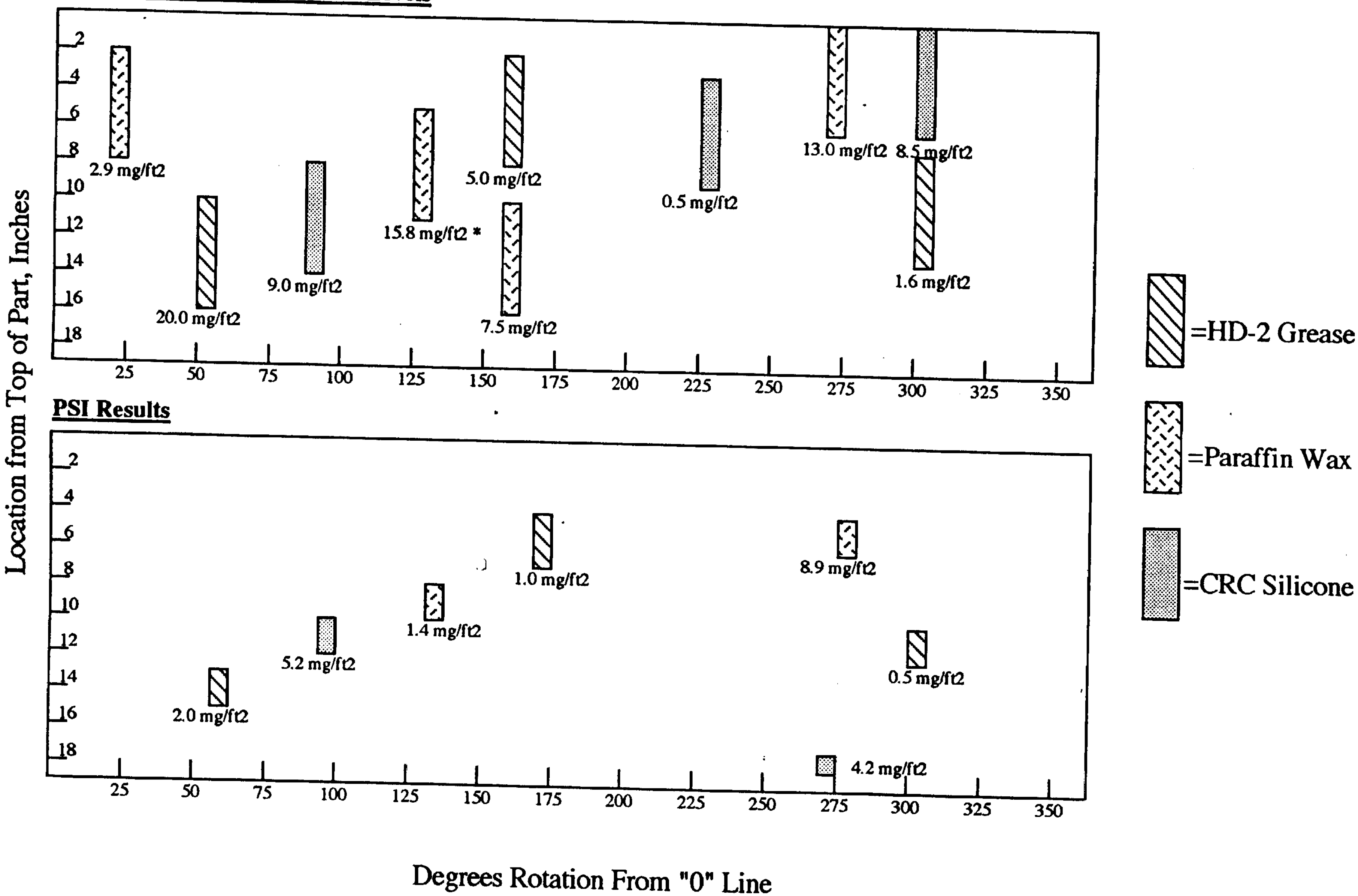
a. Evaluate additional OSEE III 6" sensors.

b. Initiate testing with SIMIR surface contamination analysis system.

c. Continue evaluation of UVF analysis system.

FIGURE I: PSI UVF Eximer Laser Demonstration-Contamination Maps

Nose Inlet Housing, 7075-T73 Aluminum



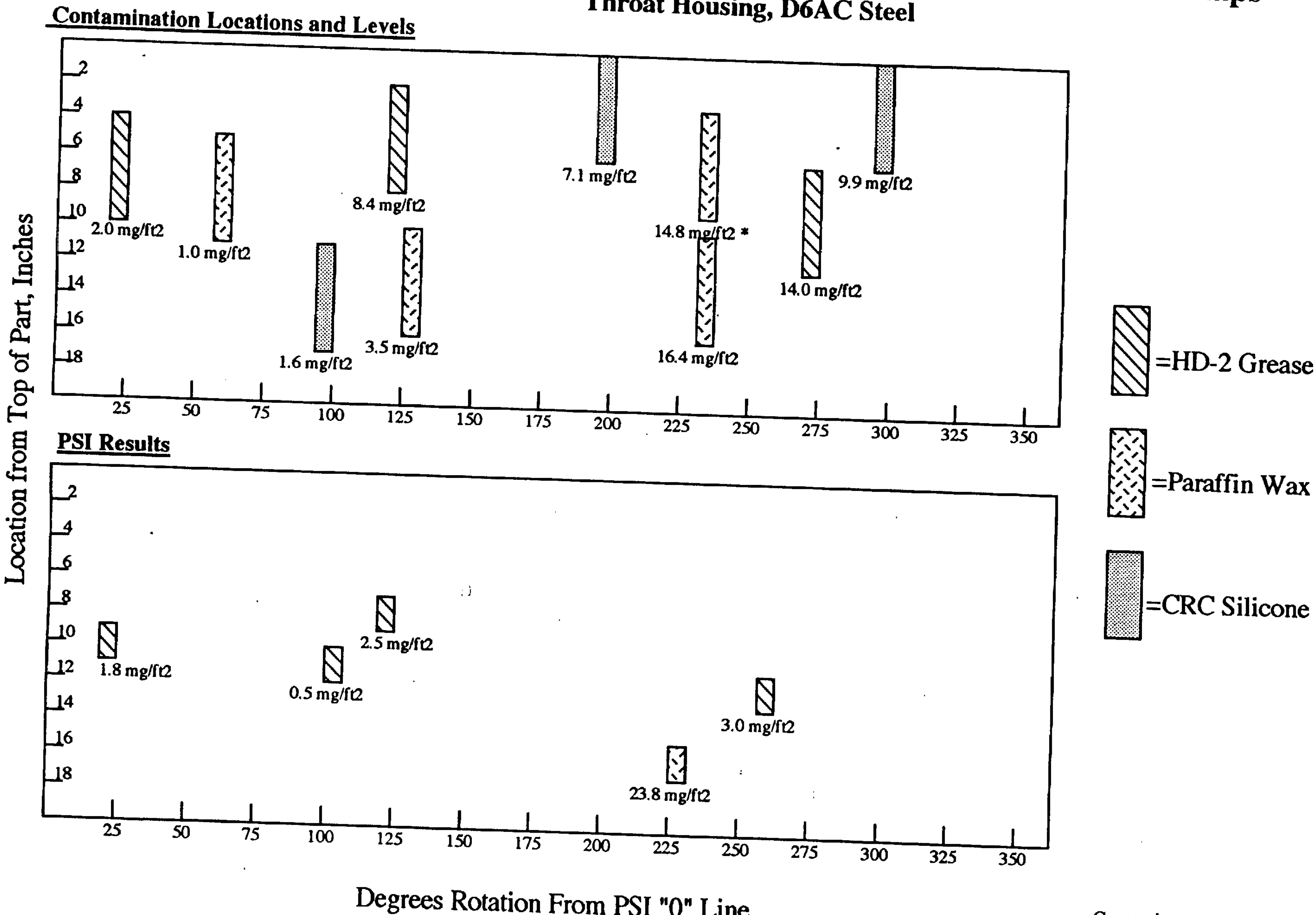
Contaminants on metallic pieces were applied in 6" x 6" patterns, and contaminants on the glass phenolic were applied in 4" x 6" patterns.

* Coating levels were suspect

AC57a/2/95

FIGURE II: PSI UVF Eximer Laser Demonstration-Contamination Maps

Throat Housing, D6AC Steel



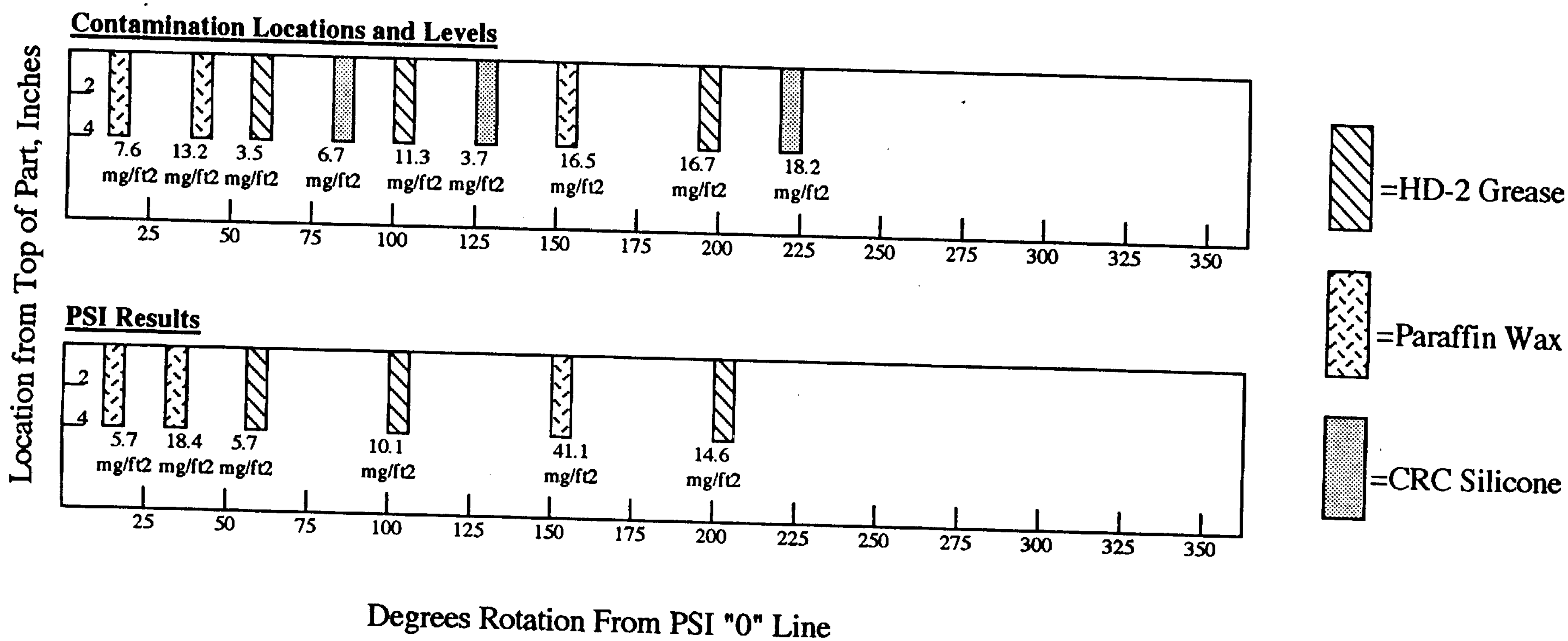
Contaminants on metallic pieces were applied in 6" x 6" patterns, and contaminants on the glass phenolic were applied in 4" x 6" patterns.

* Coating levels were suspect

AC57b/2/95

FIGURE III: PSI UVF Eximer Laser Demonstration-Contamination Maps

Forward Nose Ring, Glass Phenolic Section

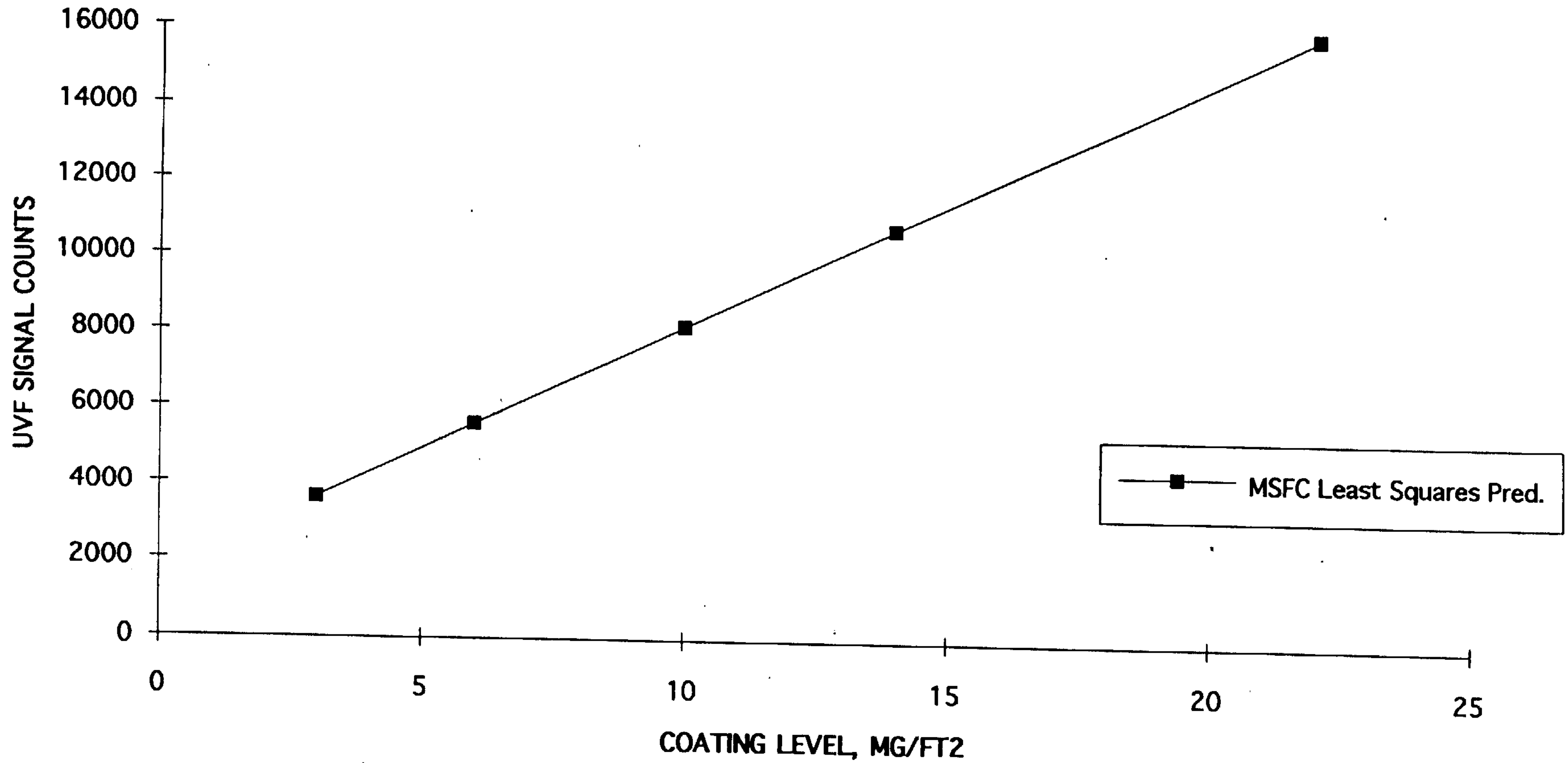


Contaminants on metallic pieces were applied in 6" x 6" patterns, and contaminants on the glass phenolic were applied in 4" x 6" patterns.

* Coating levels were suspect

AC57d/2/95

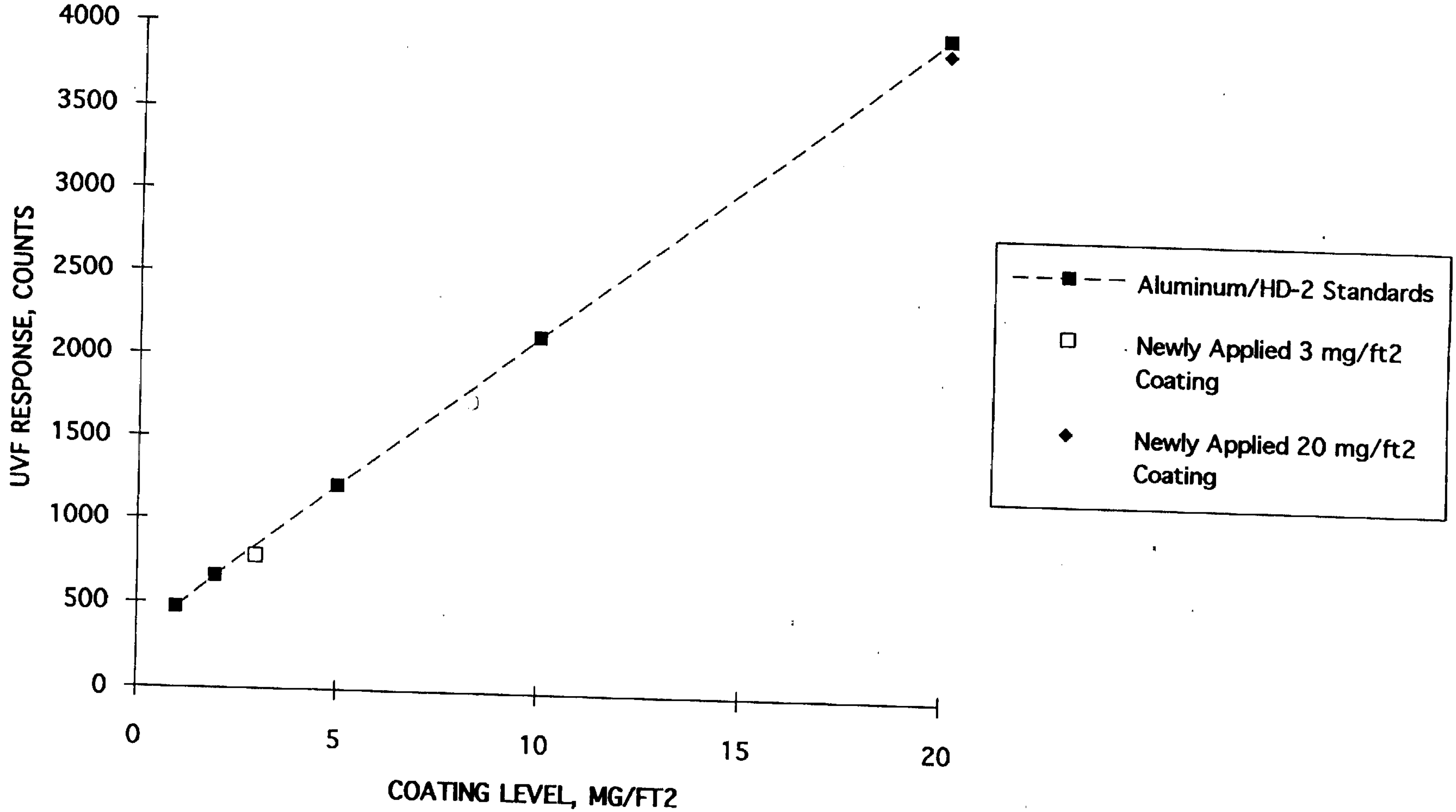
FIGURE IV: SUMMARY OF UVF ALUMINUM/HD-2 GREASE CALIBRATION DATA



50 pulses, 2 second scan time. Gain setting 4.5. Least Squares prediction based on data shown in Table AC61i/5/95.

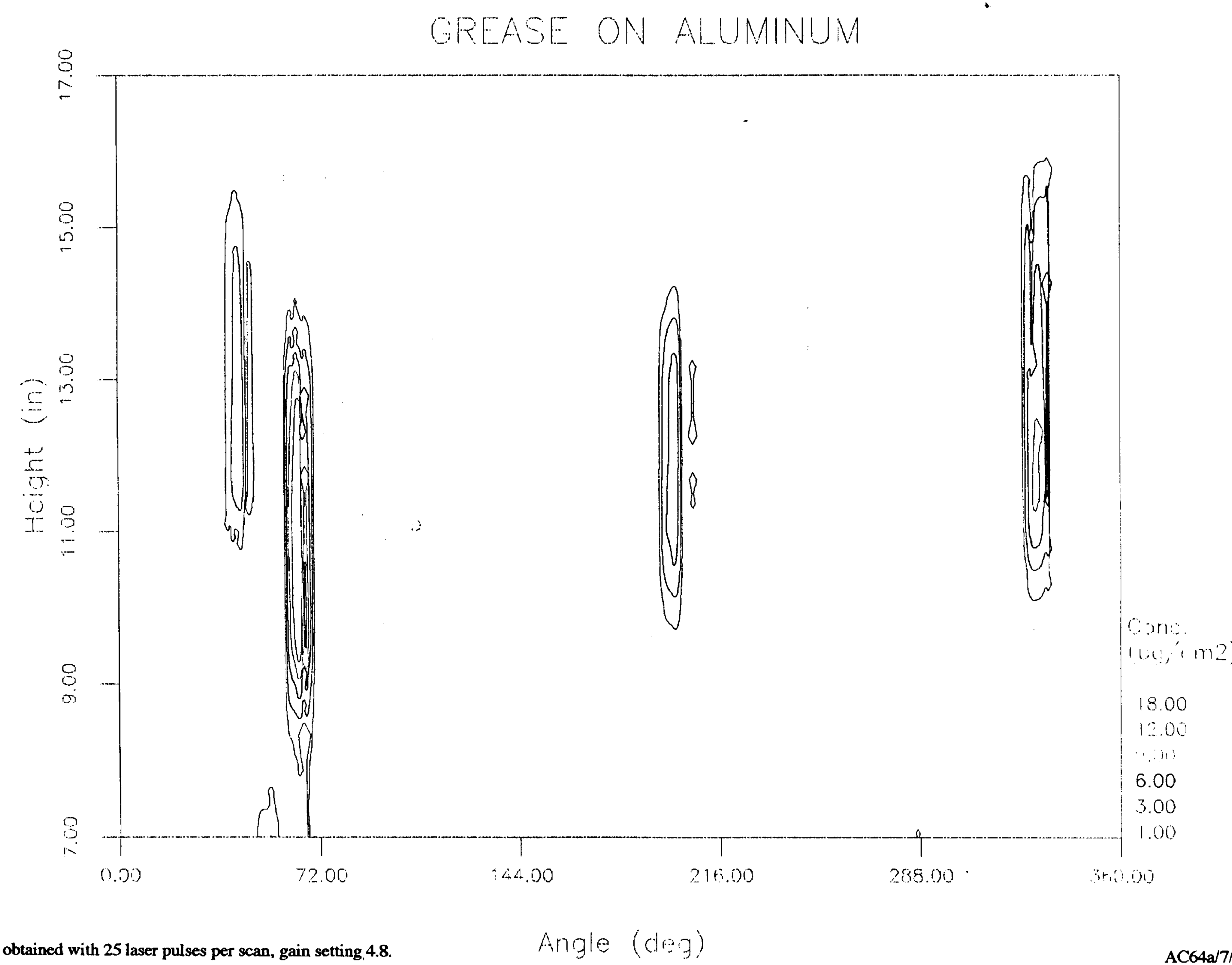
AC61h/5/95

FIGURE V: UVF RESPONSE OF ALUMINUM/HD-2 GREASE CALIBRATION STANDARDS VERSUS NEW HD-2 COATINGS APPLIED TO NOSE INLET HOUSING



25 Pulses, 2 second scan time. Gain setting 4.5. Data for calibration standards based on least squares analysis prediction of actual results.
AC62I/6/95

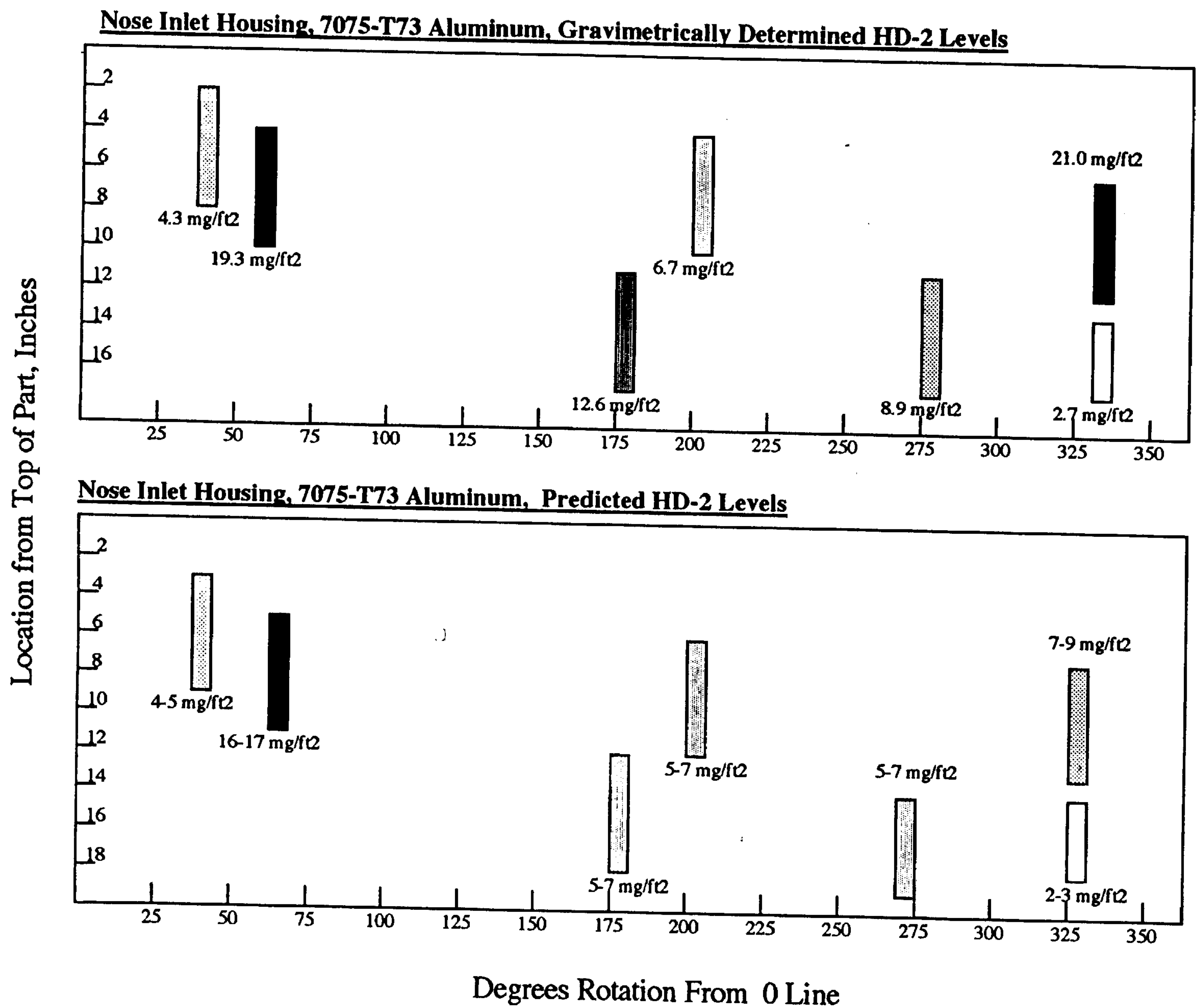
Figure VI: UVF Contour Plots Of New HD-2 Coatings Applied To Top Half Of RSRM Nose Inlet Housing Test Article



Data obtained with 25 laser pulses per scan, gain setting 4.8.

AC64a/7/95

Figure VII: UVF Eximer Laser Evaluation-Contamination Maps Of New HD-2 Coatings



AC64b/7/95

Contaminants were applied in 6" x 6" or 4" x 6" patterns

FIGURE VIII

FLOW DIAGRAM FOR NIR TAPE RESIDUE STUDIES

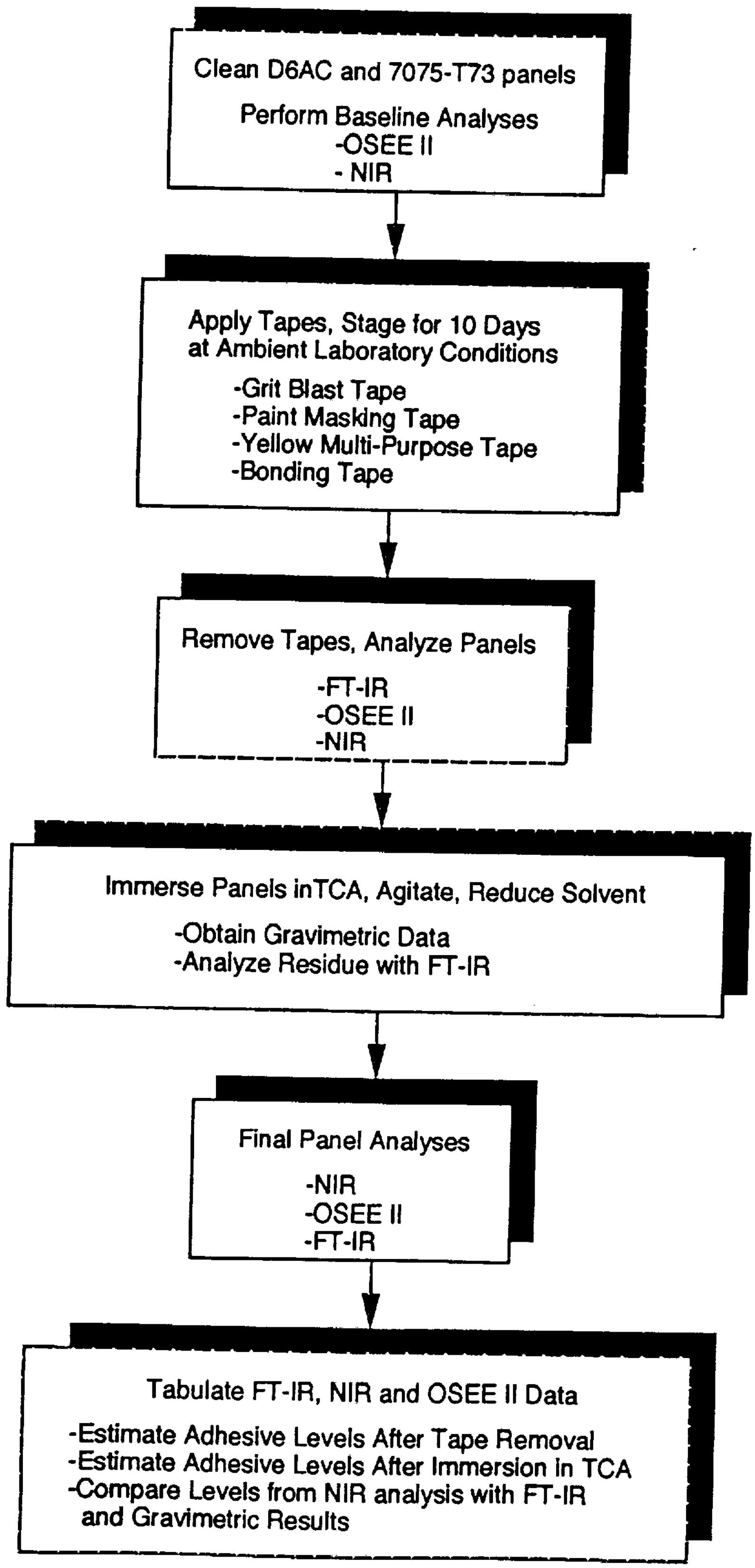
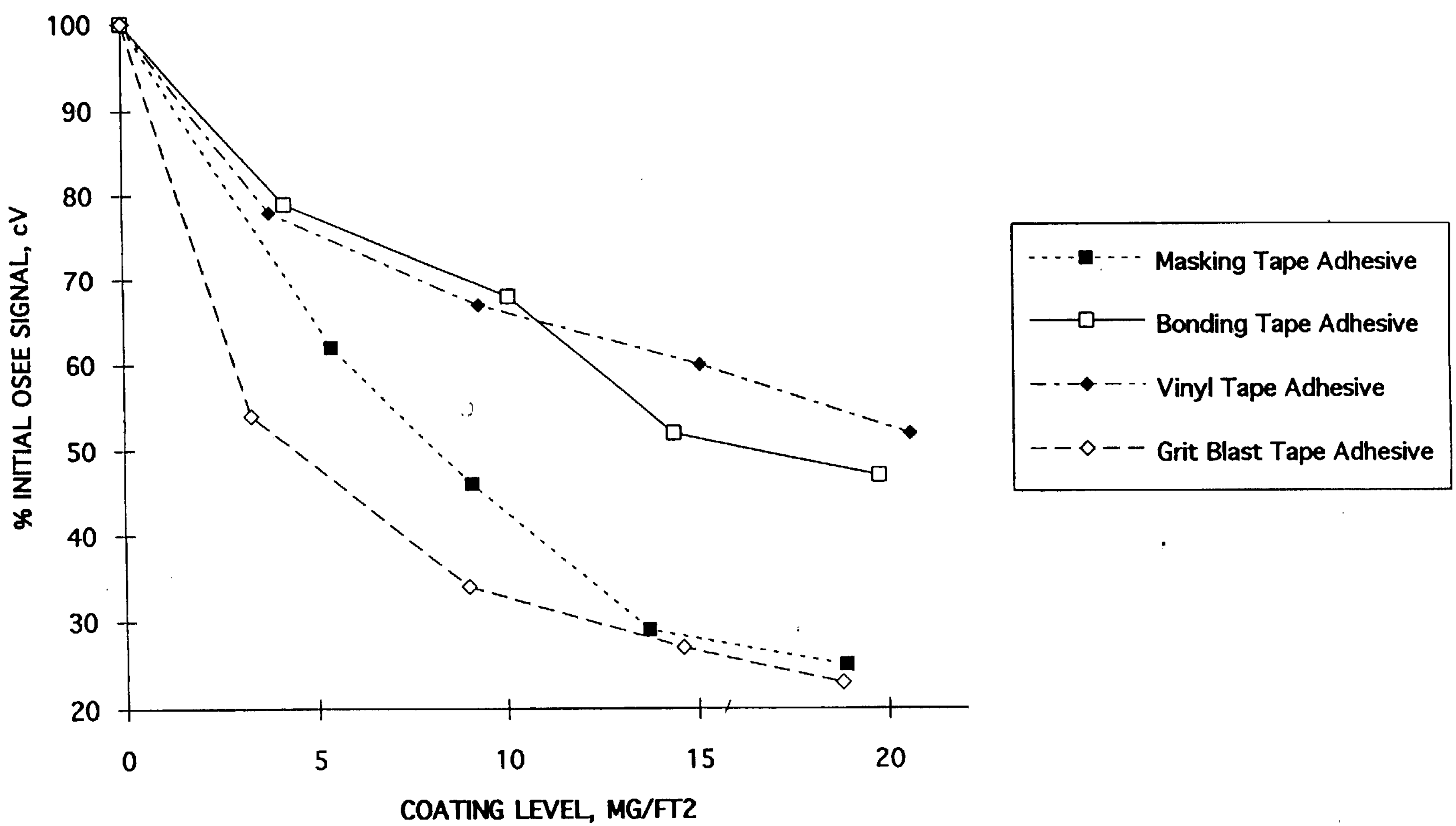


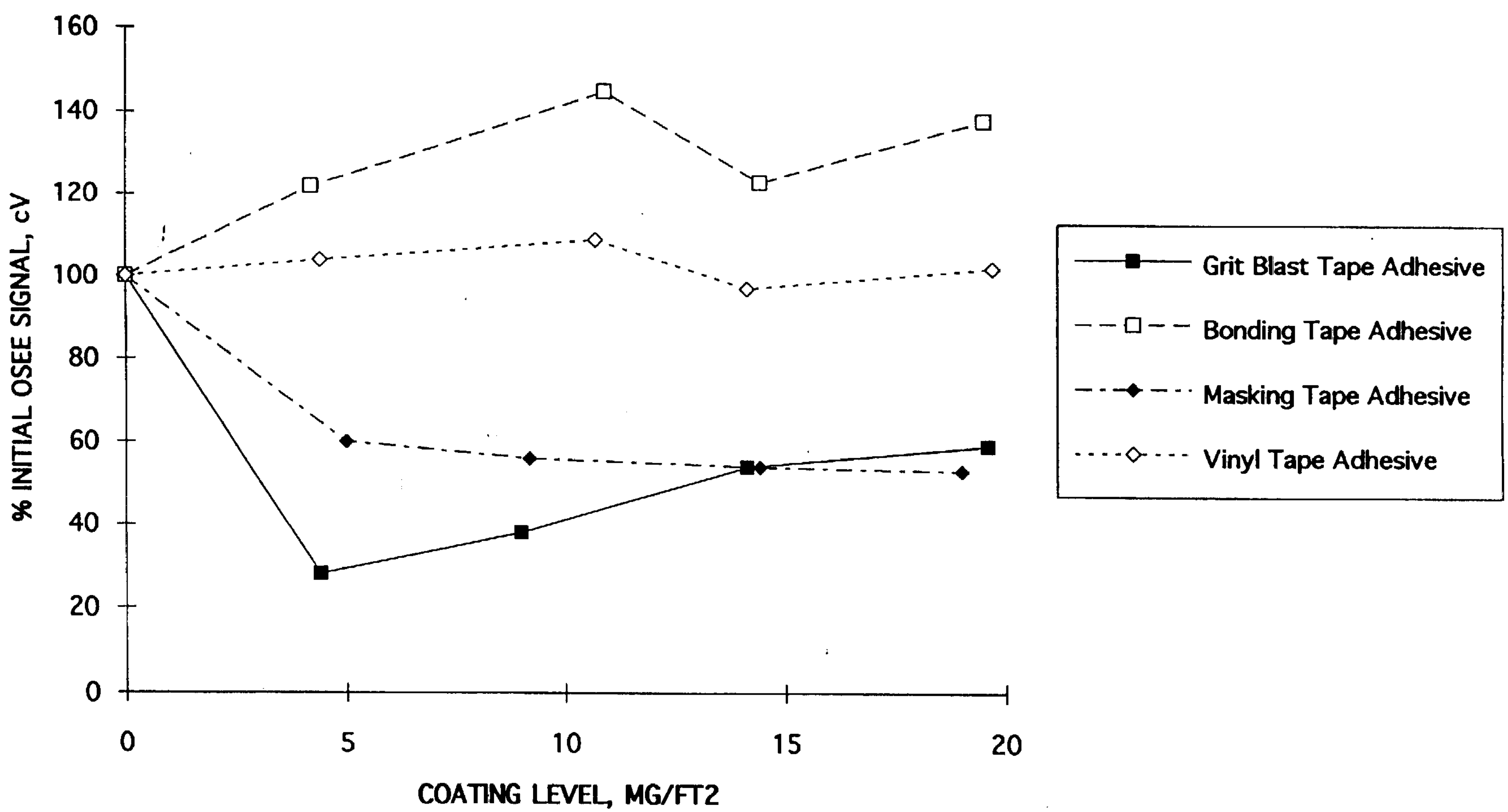
FIGURE IX: OSEE II ANALYSIS OF ALUMINUM TAPE RESIDUE CALIBRATION STANDARDS



Calibration standards prepared by spray applying mixtures of adhesives and methyl chloroform. Coating levels determined by measuring weight changes of aluminum foil witness samples. OSEE standoff was app. 1/8".

AC61c/5/95

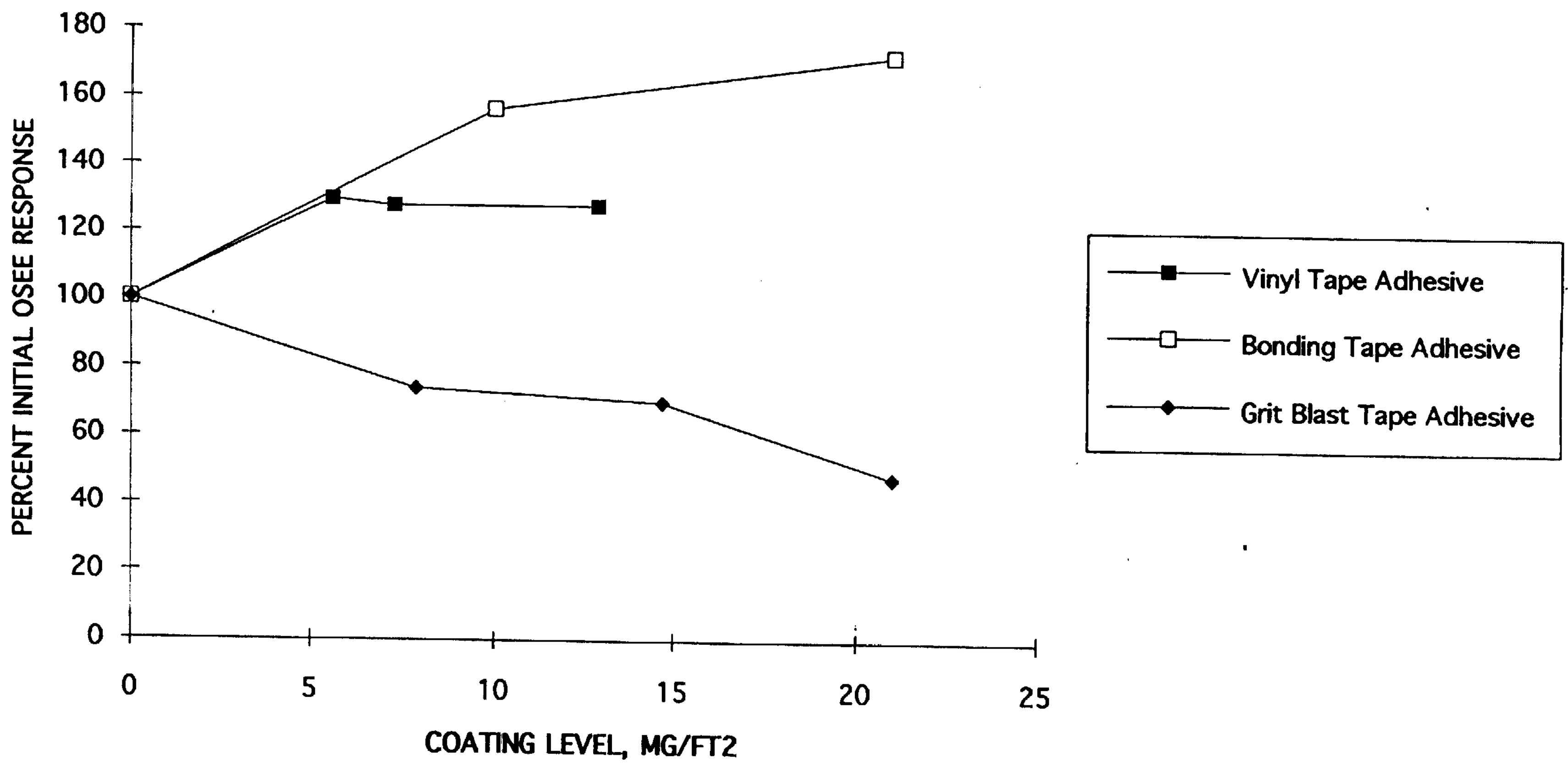
FIGURE X: OSEE II ANALYSIS OF D6AC TAPE RESIDUE CALIBRATION STANDARDS



Calibration standards prepared by spray applying mixtures of adhesives and methyl chloroform. Coating levels determined by measuring weight changes of aluminum foil witness samples. OSEE Standoff was 1/4".

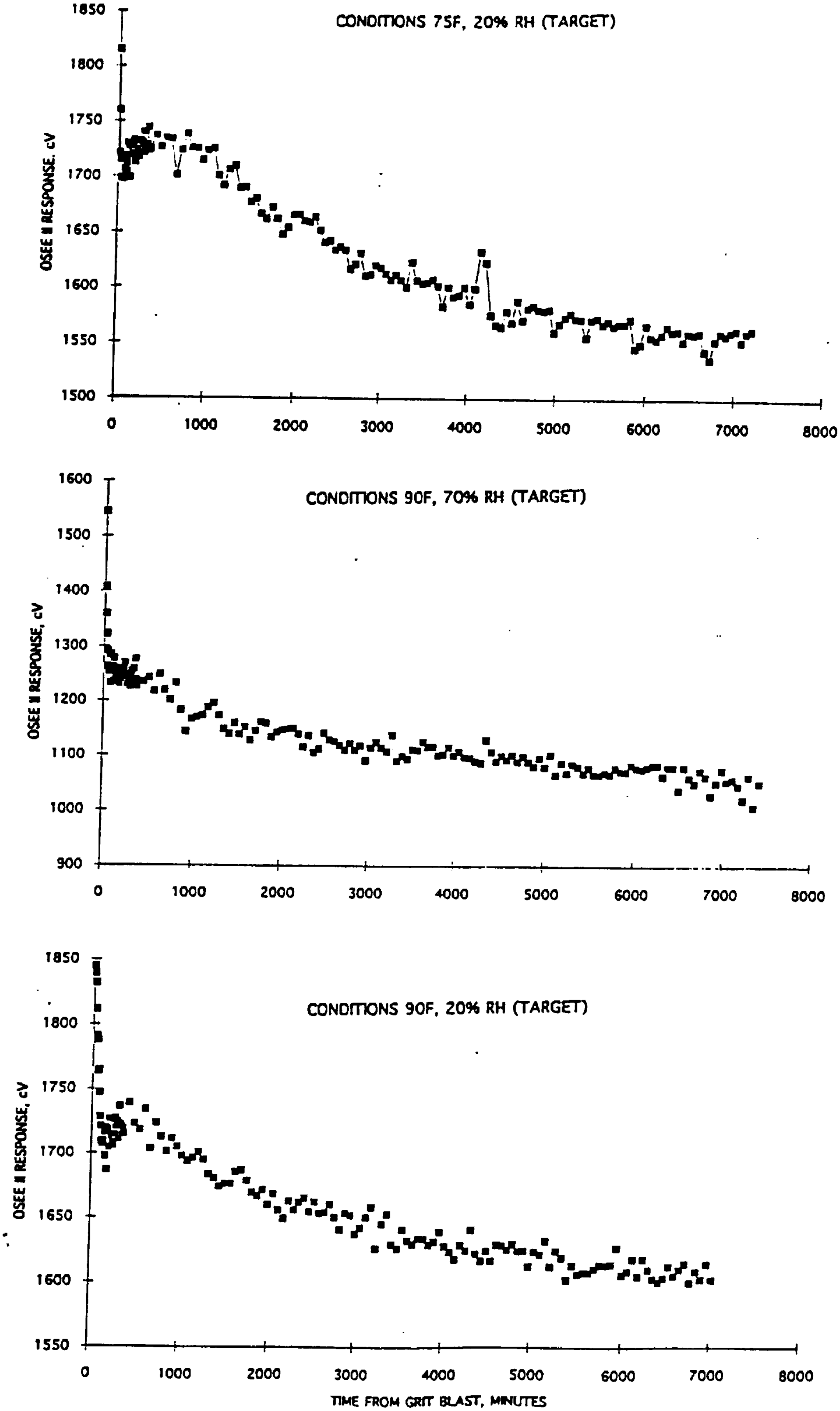
AC61d/5/95

FIGURE XI: OSEE II SIGNALS VERSUS COATING LEVELS FOR VINYL, BONDING, AND GRIT BLAST TAPE ADHESIVES ON D6AC STEEL, TRIAL 2



Calibration standards prepared by spray applying mixtures of adhesives and methyl chloroform. Coating levels determined by measuring weight changes of aluminum foil witness samples. Initial OSEE responses 450-500 cV. AC61j/5/95

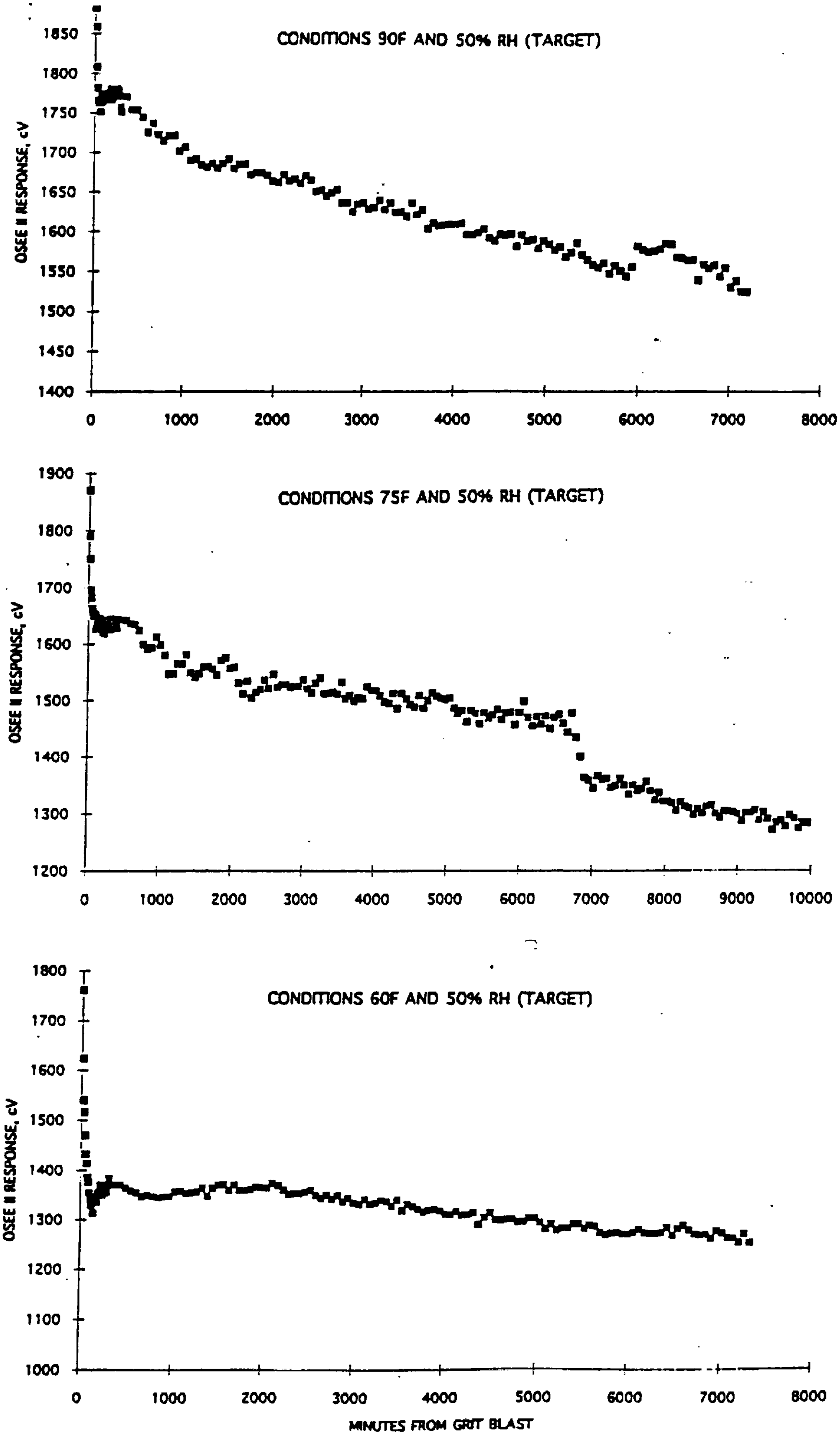
FIGURE XII: OSEE II ANALYSIS RESULTS FOR GRIT BLASTED LiAl



AC67G/9/95

Grit blast angle 20 degrees, sensor stand-off distance 1/4".

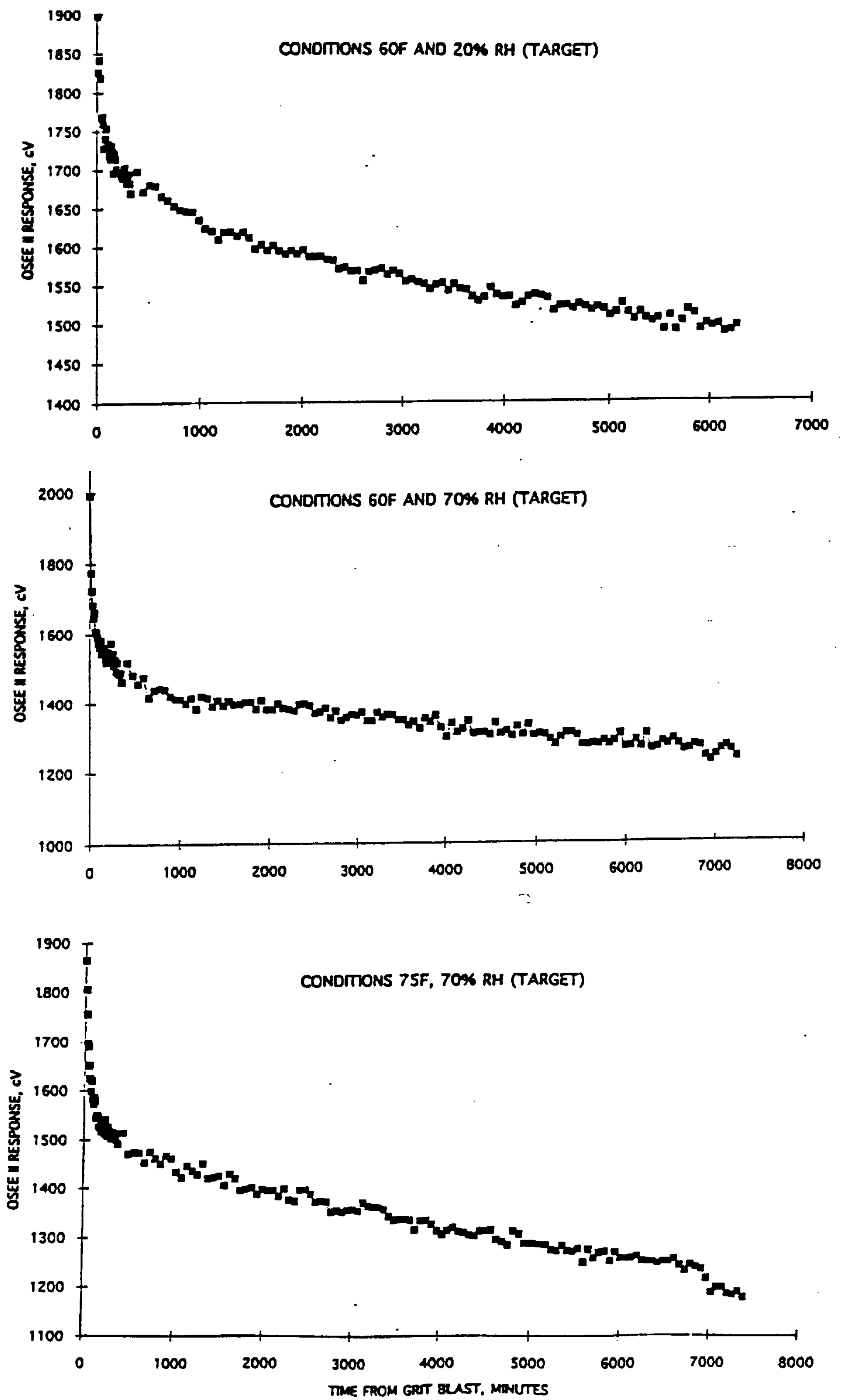
FIGURE XIII: OSEE II ANALYSIS RESULTS FOR GRIT BLASTED LiAl



AC67F/9/95

Grit blast angle 20 degrees, sensor stand-off distance 1/4".

FIGURE XIV: OSEE II ANALYSIS RESULTS FOR GRIT BLASTED LiAl

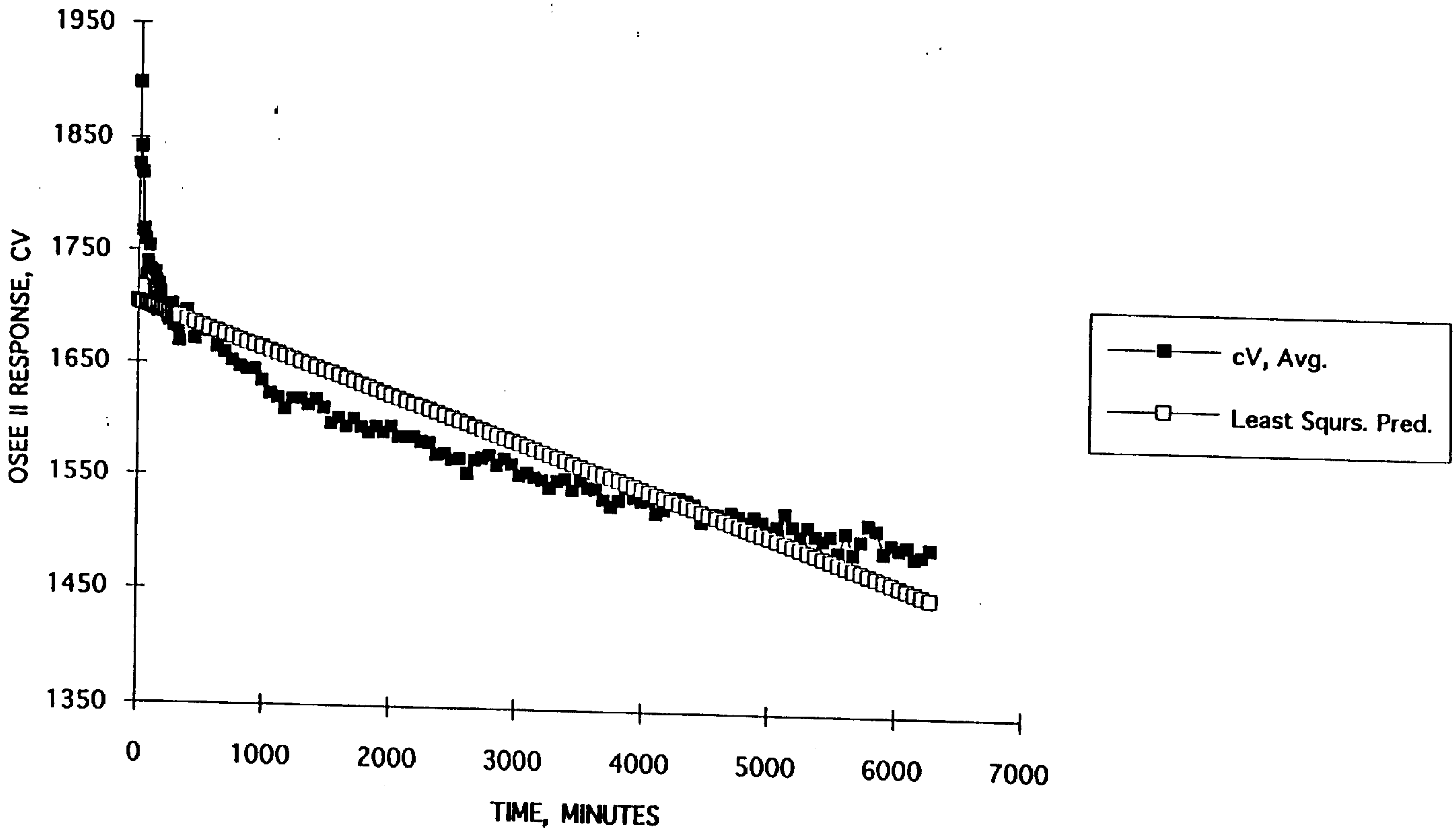


Grit blast angle 20 degrees, sensor stand-off distance 1/4".

AC67H/9/95

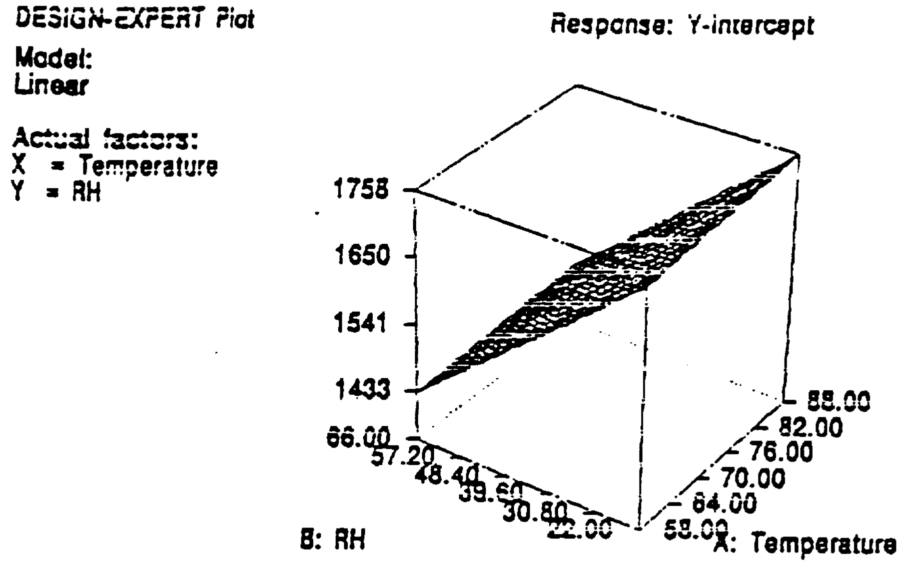
FIGURE XV

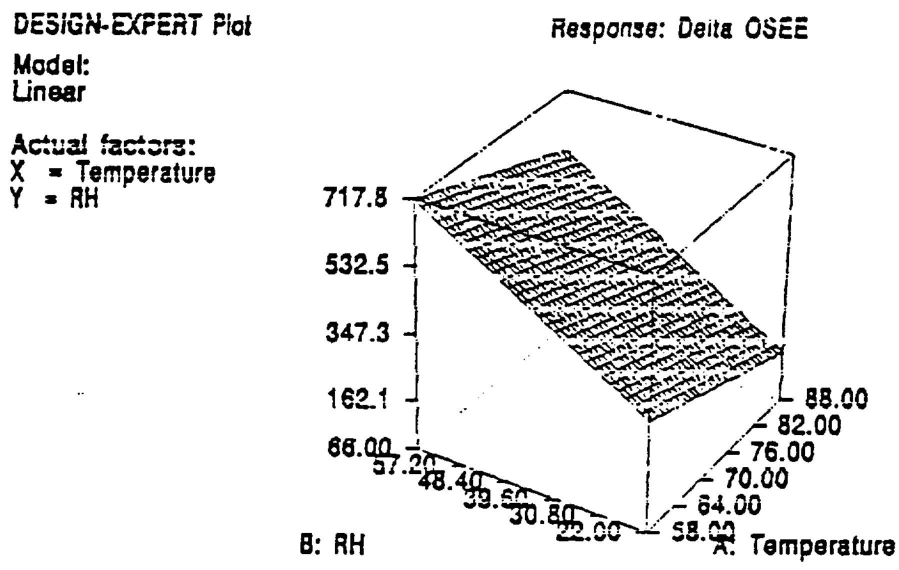
LINEAR REGRESSION ANALYSIS OF OSEE II DATA FROM GRIT BLASTED LiAl AT 60F/20% RH



Grit blast angle 20 degrees, stand-off distance 1/4".

FIGURE XVI: 3-D CONTOUR PLOTS OF LiAl ANALYSIS RESULTS





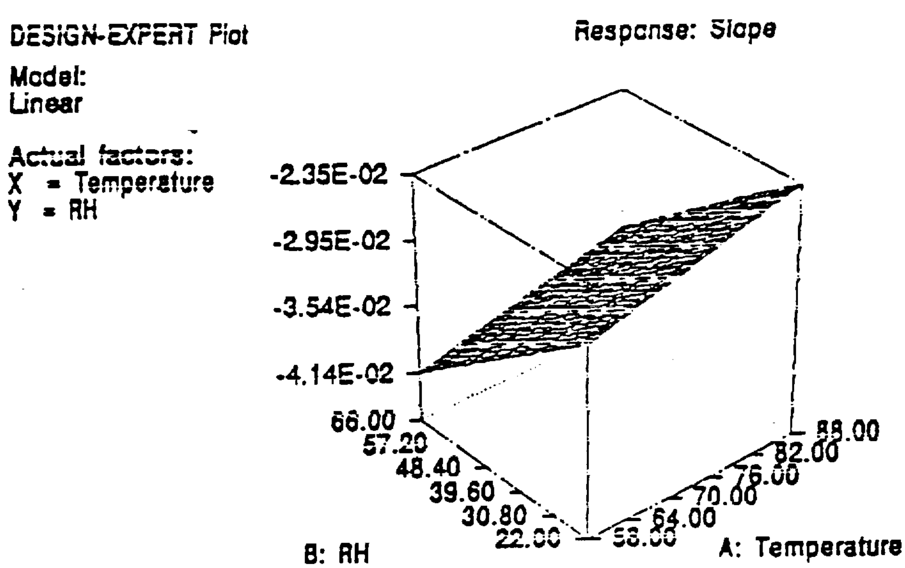
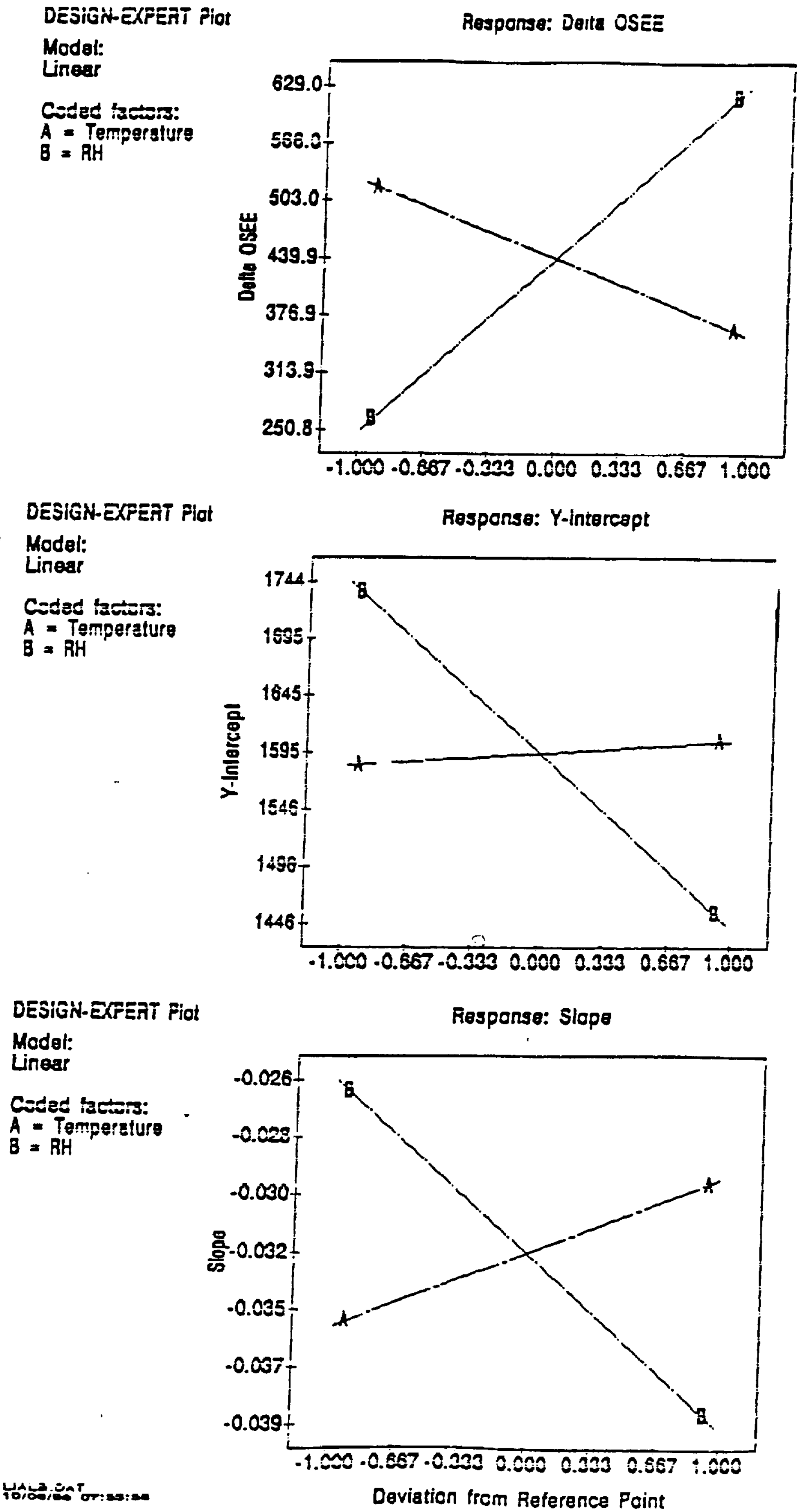
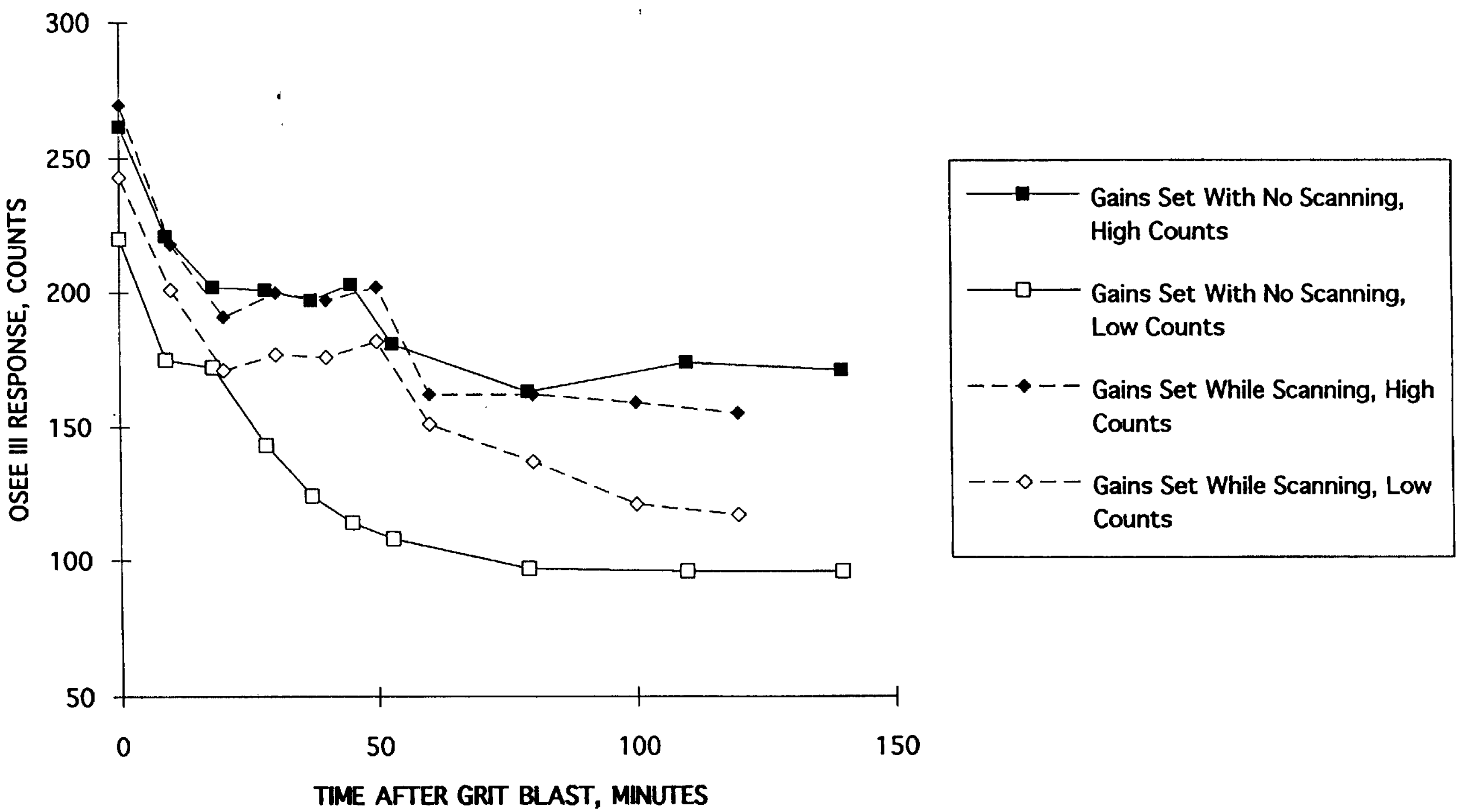


FIGURE XVII: PERTURBATION PLOTS OF LiAl ANALYSIS RESULTS



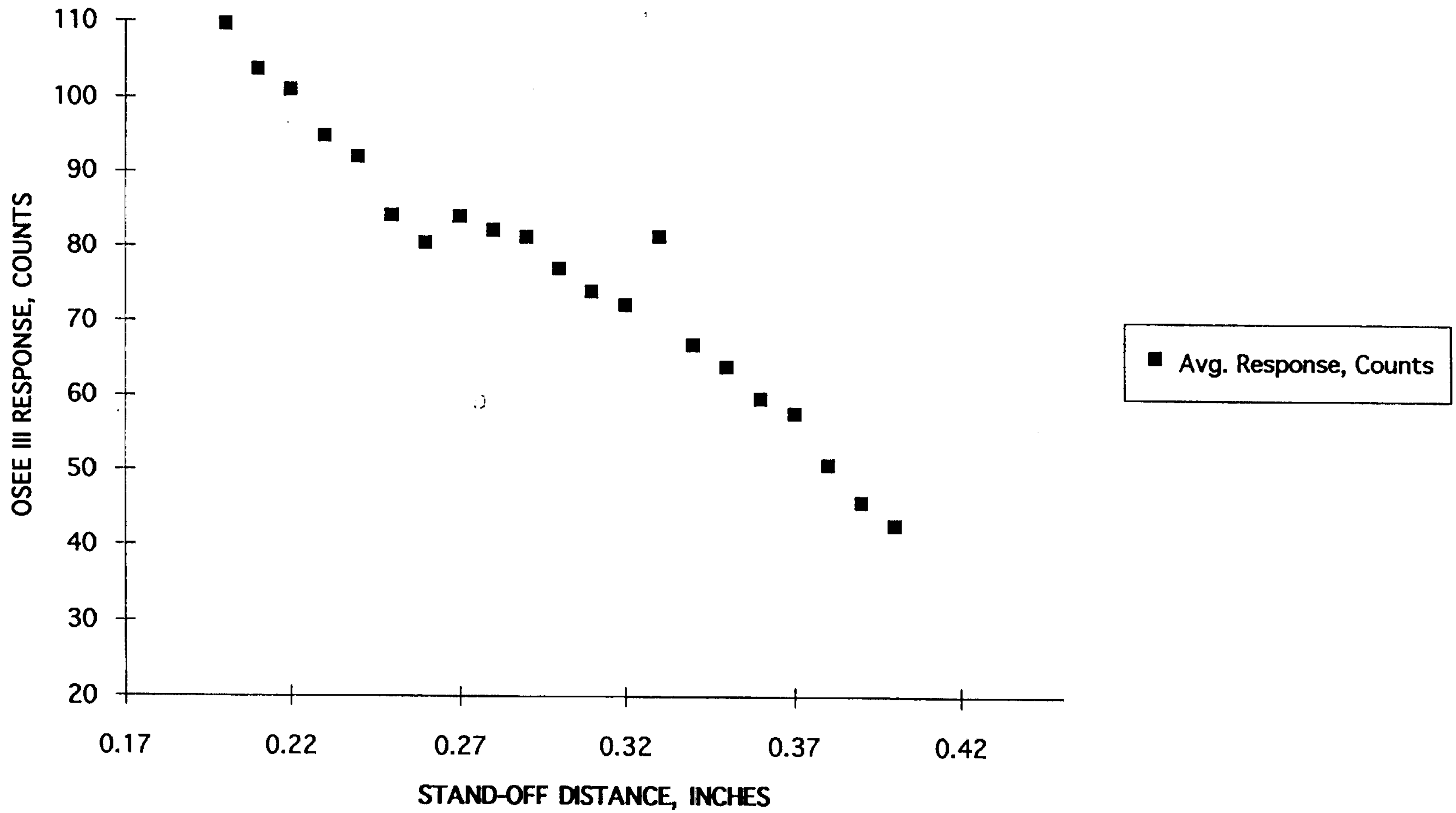
AC68S/10/95

FIGURE XVIII: COMPARISON OF HIGH AND LOW RESPONSES FOR GRIT BLASTED STEEL WITH TWO GAIN CALIBRATION PROCEDURES



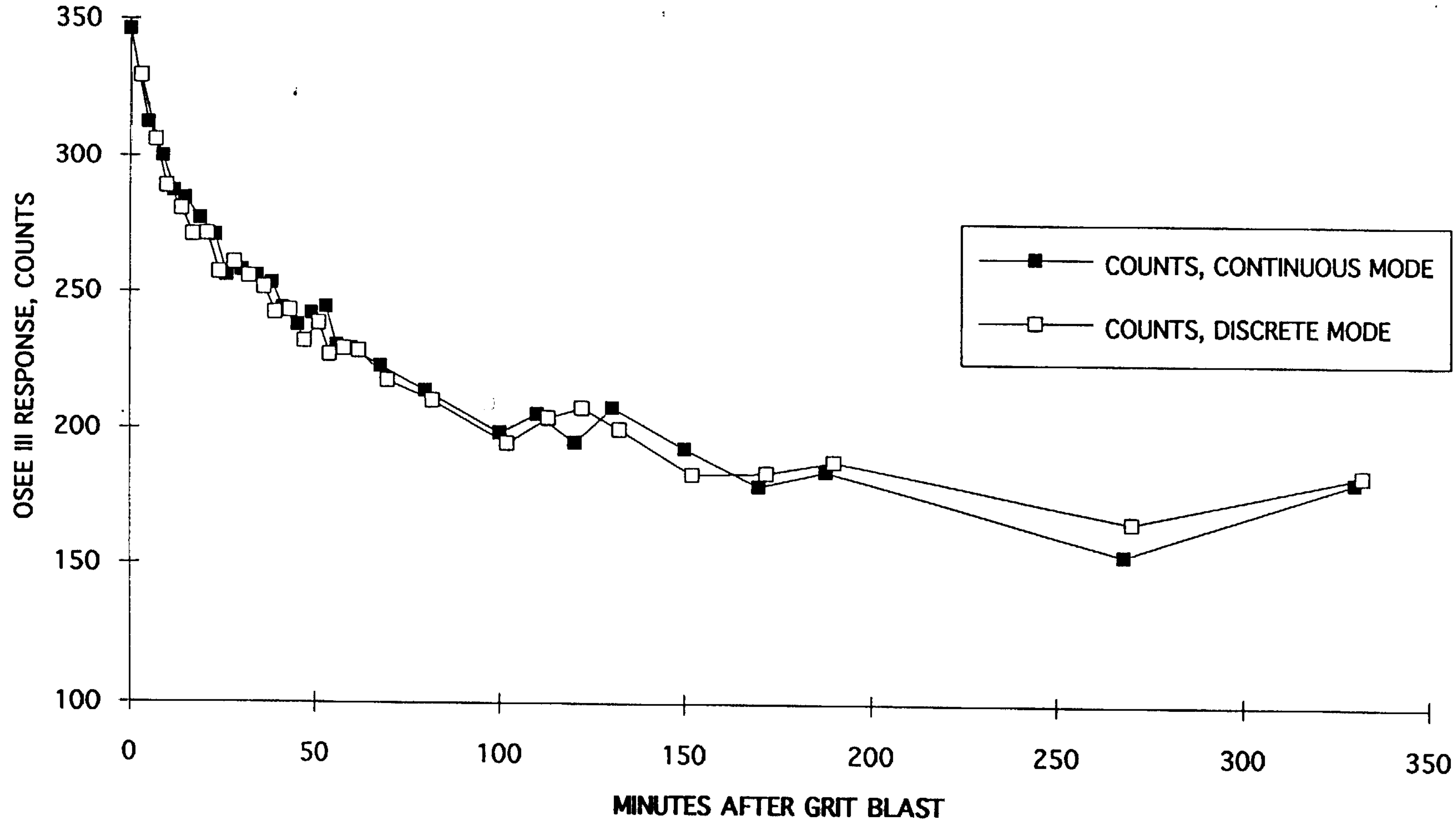
Stand-off distance 1/4". Scan rate 2, 0 second delay. AC69B/12/95

FIGURE XIX: EFFECT OF STAND-OFF DISTANCE ON OSEE III RESPONSE OF D6AC STEEL, SENSOR #4



A passivated D6AC steel panel was used for the tests. The panel measured 480 cV on OSEE II. Scan speed 2, 0 second delay time, continuous scanning mode. Results are averages of three measurements per stand-off distance. AC64o/7/95

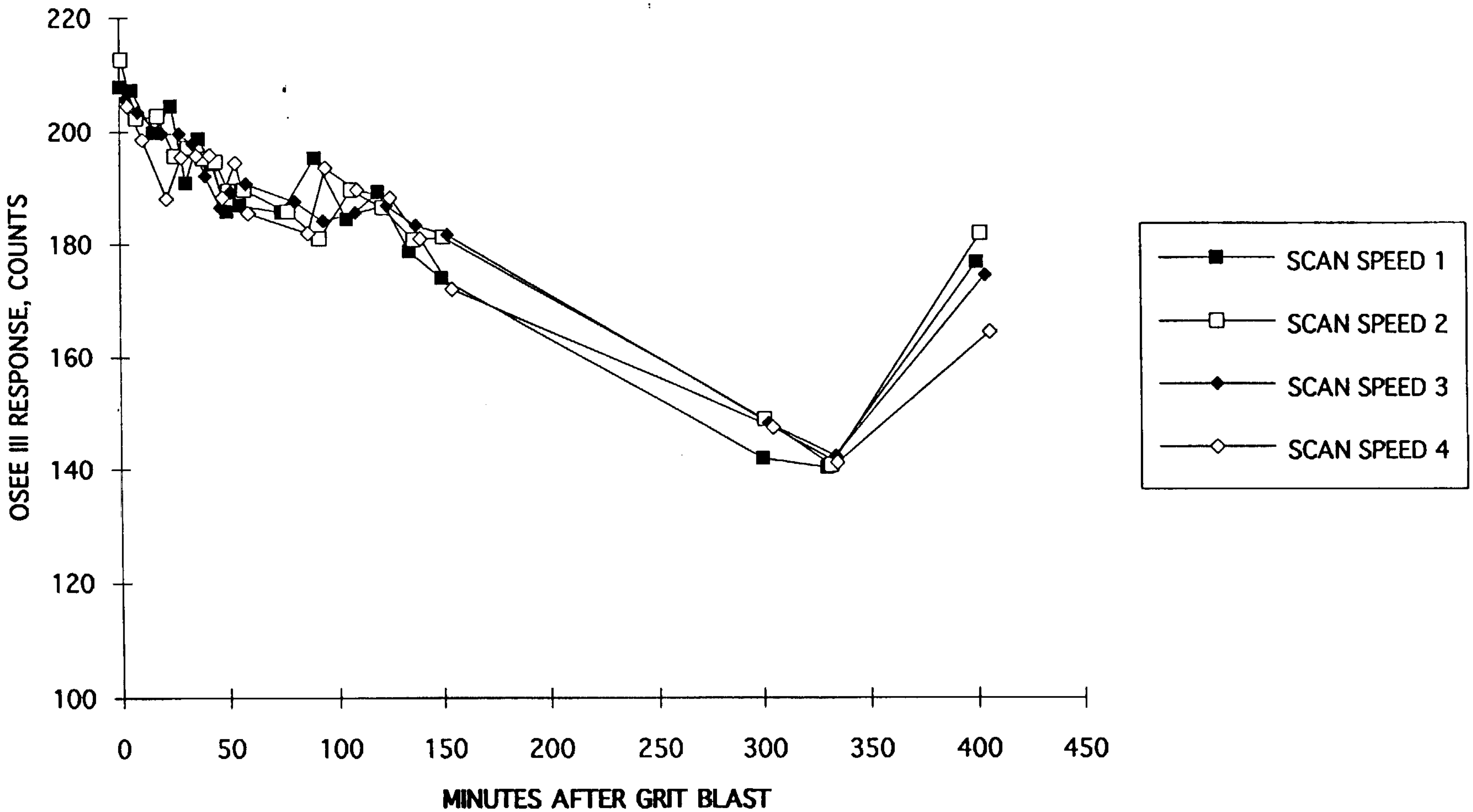
FIGURE XX: OSEE III ANALYSIS OF GRIT BLASTED D6AC STEEL USING CONTINUOUS AND DISCRETE SCANNING MODES, SENSOR #4



Panel grit blasted at 20 degrees. Sensor stand-off distance 1/4", 0 second delay time, scan speed 2.

AC65G/8/95

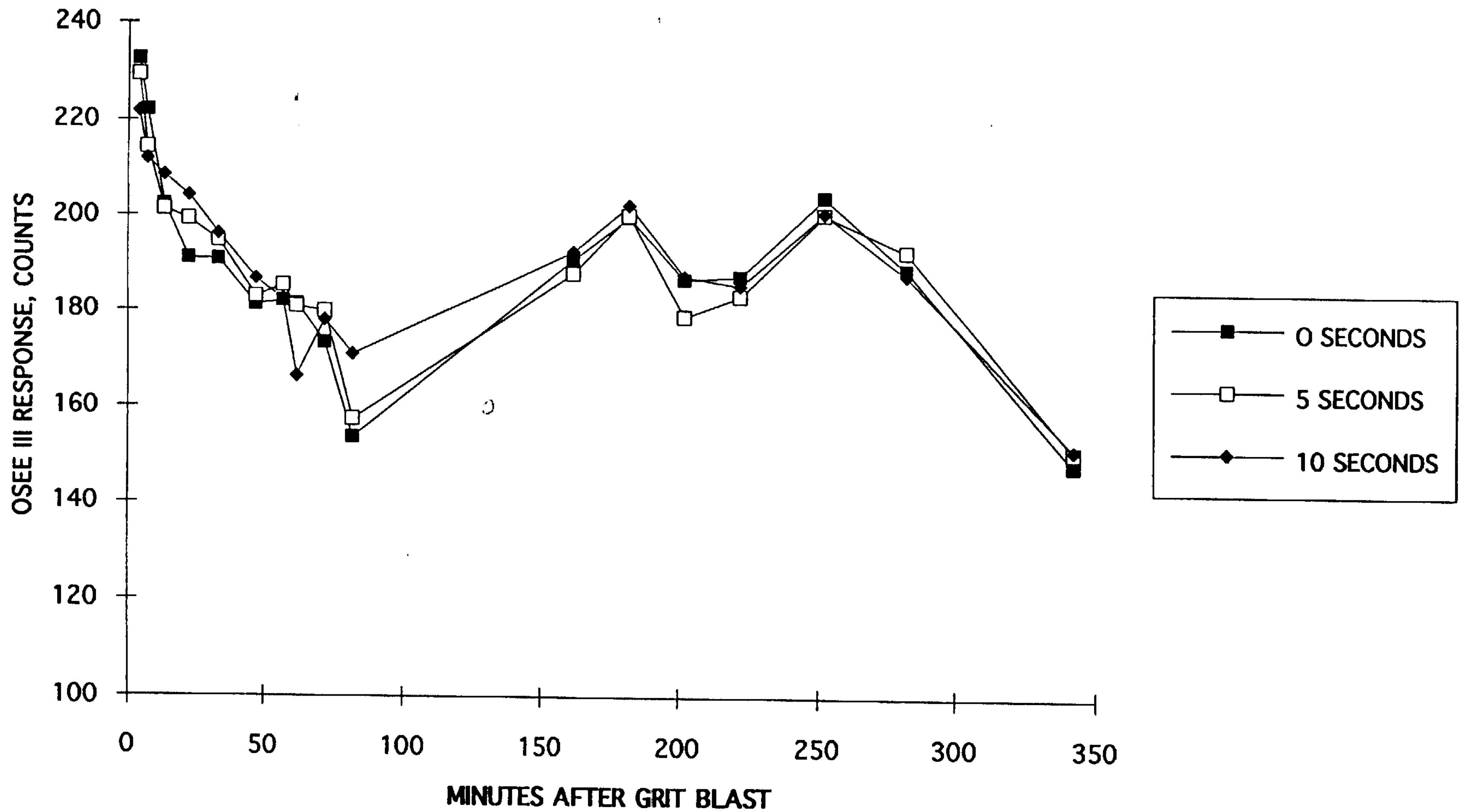
FIGURE XXI: OSEE III ANALYSIS OF GRIT BLASTED D6AC STEEL WITH SCAN SPEEDS FROM 1-4 INCHES/SECOND, SENSOR #4



Panel was grit blasted at 20 degrees. Sensor stand-off distance 1/4", 0 second delay, continuous scanning mode. Scan speeds are inches/second.

AC65I/8/95

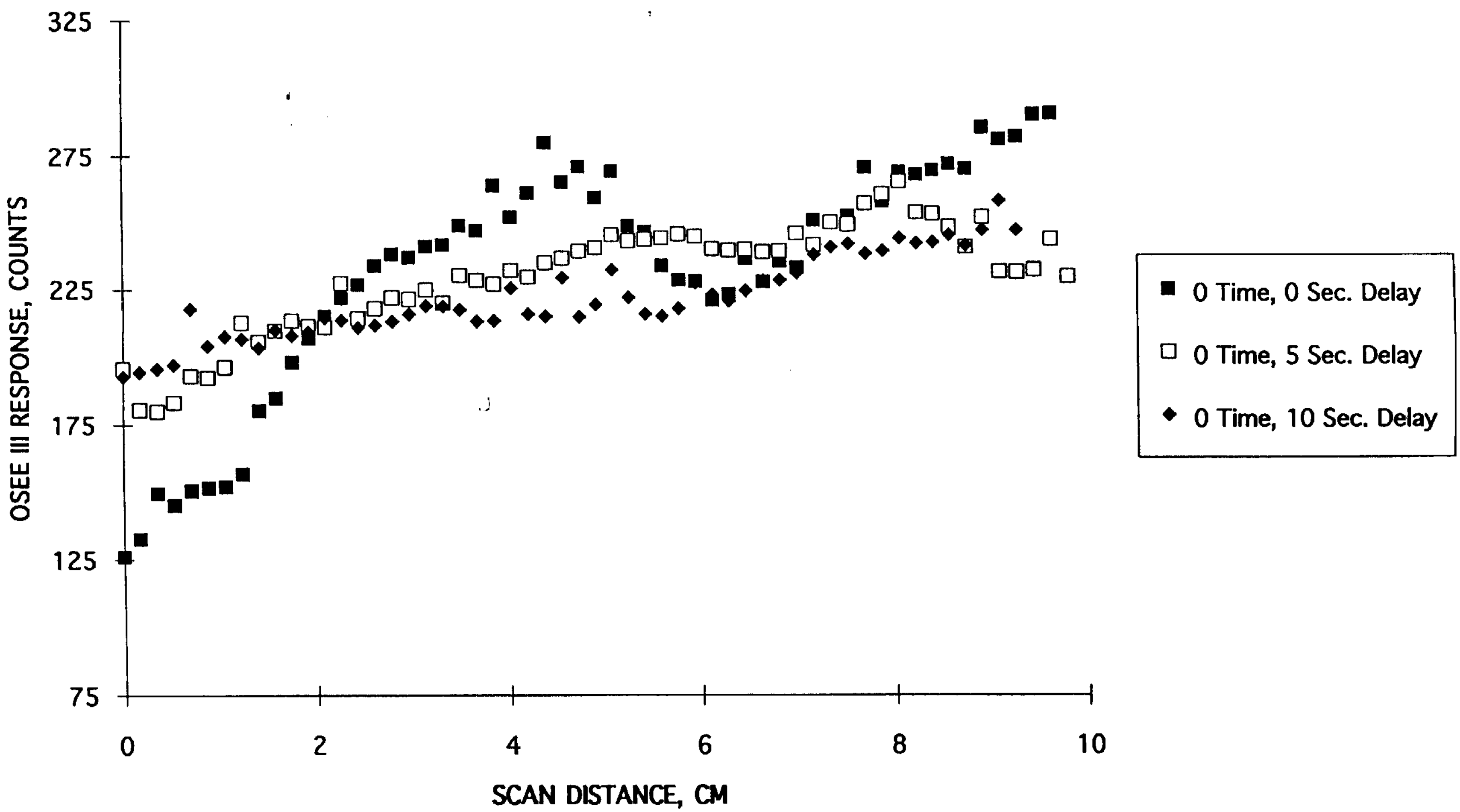
FIGURE XXII: EFFECT OF SENSOR DWELL TIME ON OSEE III RESPONSE OF GRIT BLASTED D6AC STEEL, SENSOR #4



Grit blast angle 20 degrees, sensor stand-off distance 1/4", continuous scanning mode, scan speed 2.

AC65K/8/95

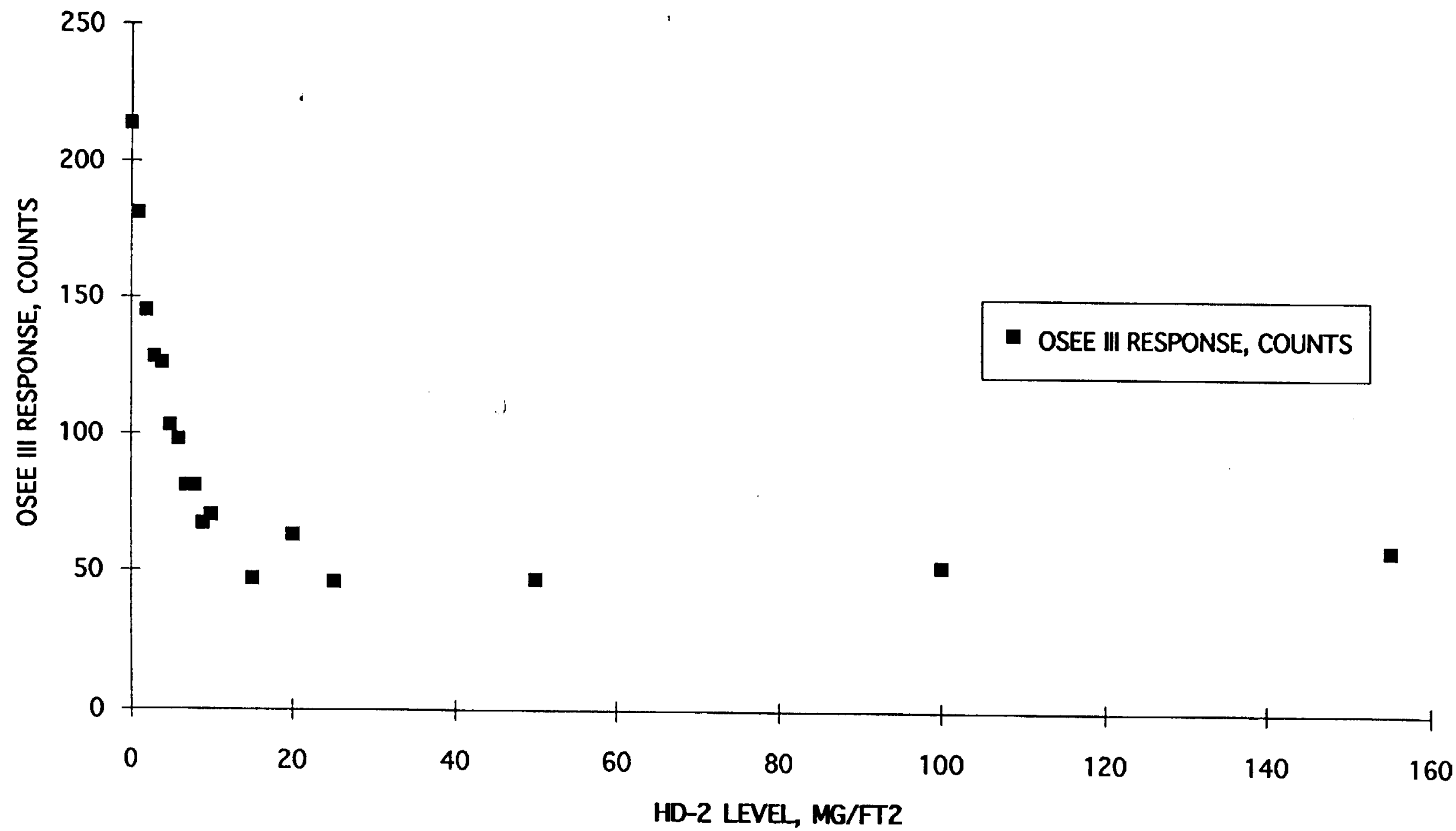
FIGURE XXIII: EFFCT OF SENSOR DWELL TIME ON OSEE III RESPONSE OF GRIT BLASTED D6AC STEEL, 6" SENSOR #4



Grit blast angle 20 degrees, stand-off distance 1/4", continuous scanning mode, scan speed 2.

AC65M/8/95

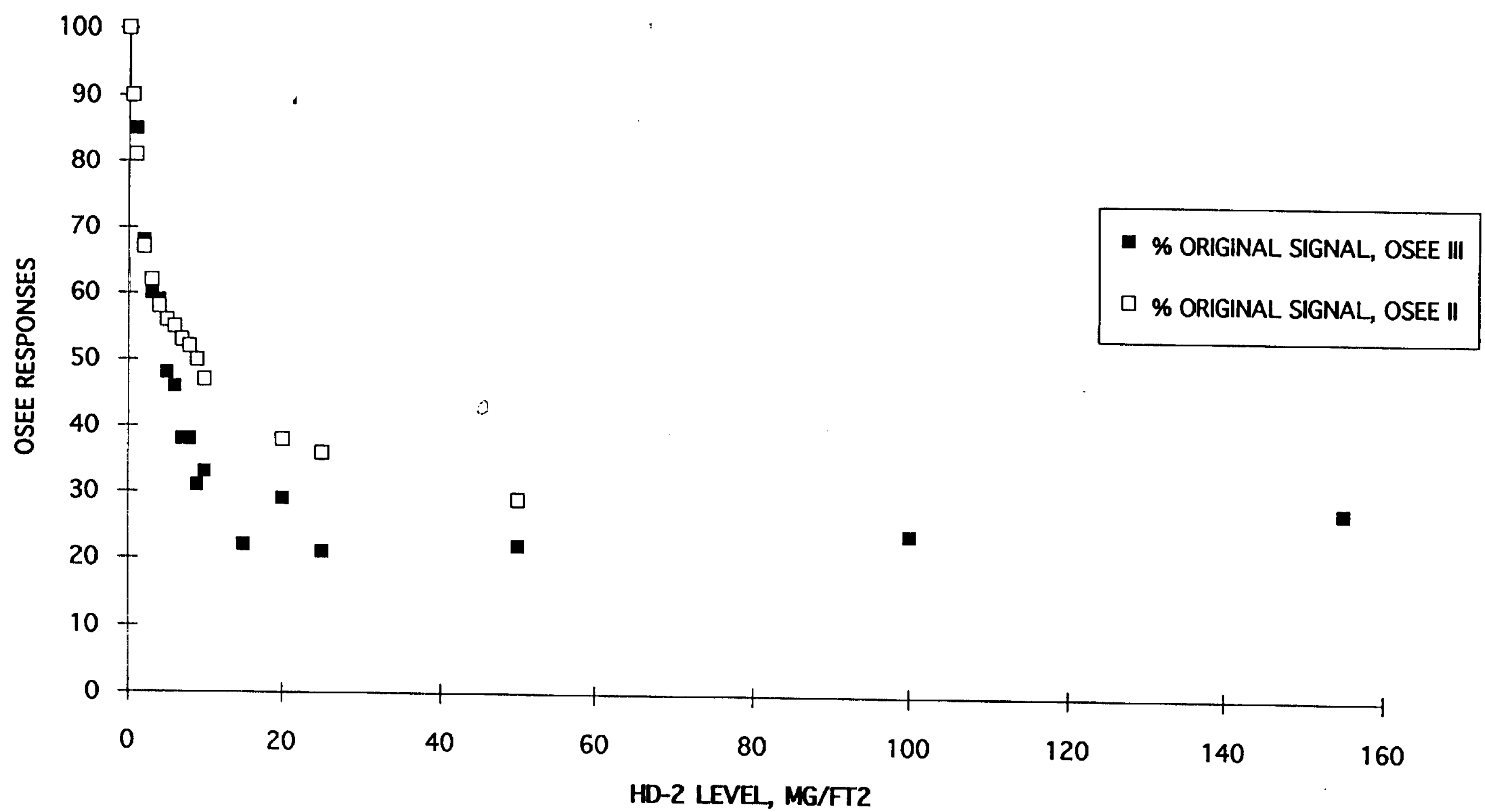
FIGURE XXIV: EFFECT OF HD-2 GREASE CONTAMINATION ON OSEE III RESPONSE OF D6AC STEEL, SENSOR #4



Sensor stand-off distance 1/4", continuous scanning mode, scan speed 2, 0 second dwell time.

AC65P/8/95

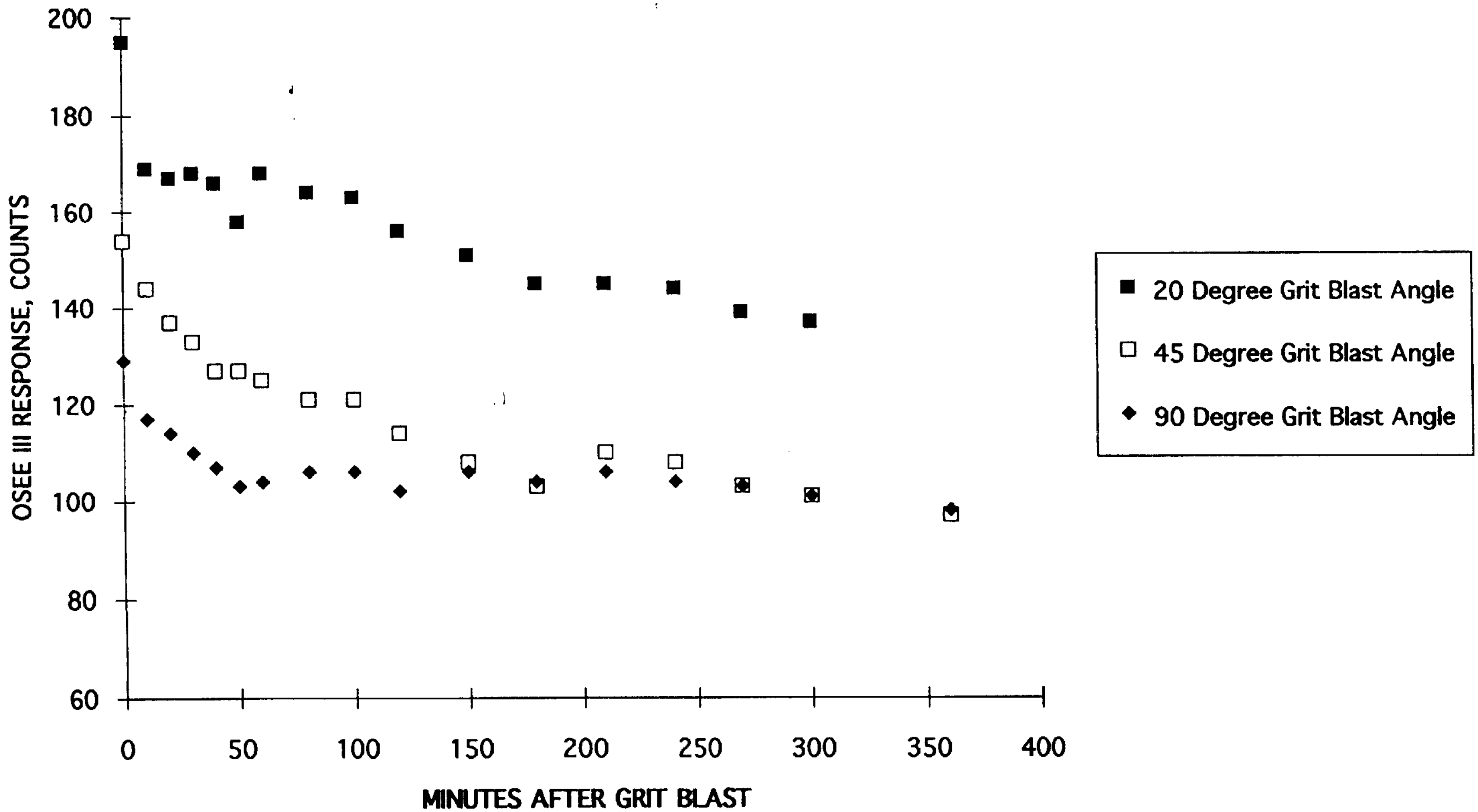
FIGURE XXV: EFFECT OF HD-2 GREASE CONTAMINATION ON OSEE II AND OSEE III RESPONSES OF D6AC STEEL



Sensor stand-off distances for OSEE III and OSEE II were 1/4". OSEE III analyses were performed at scan speed 2, continuous scanning mode, and 0 second dwell time.

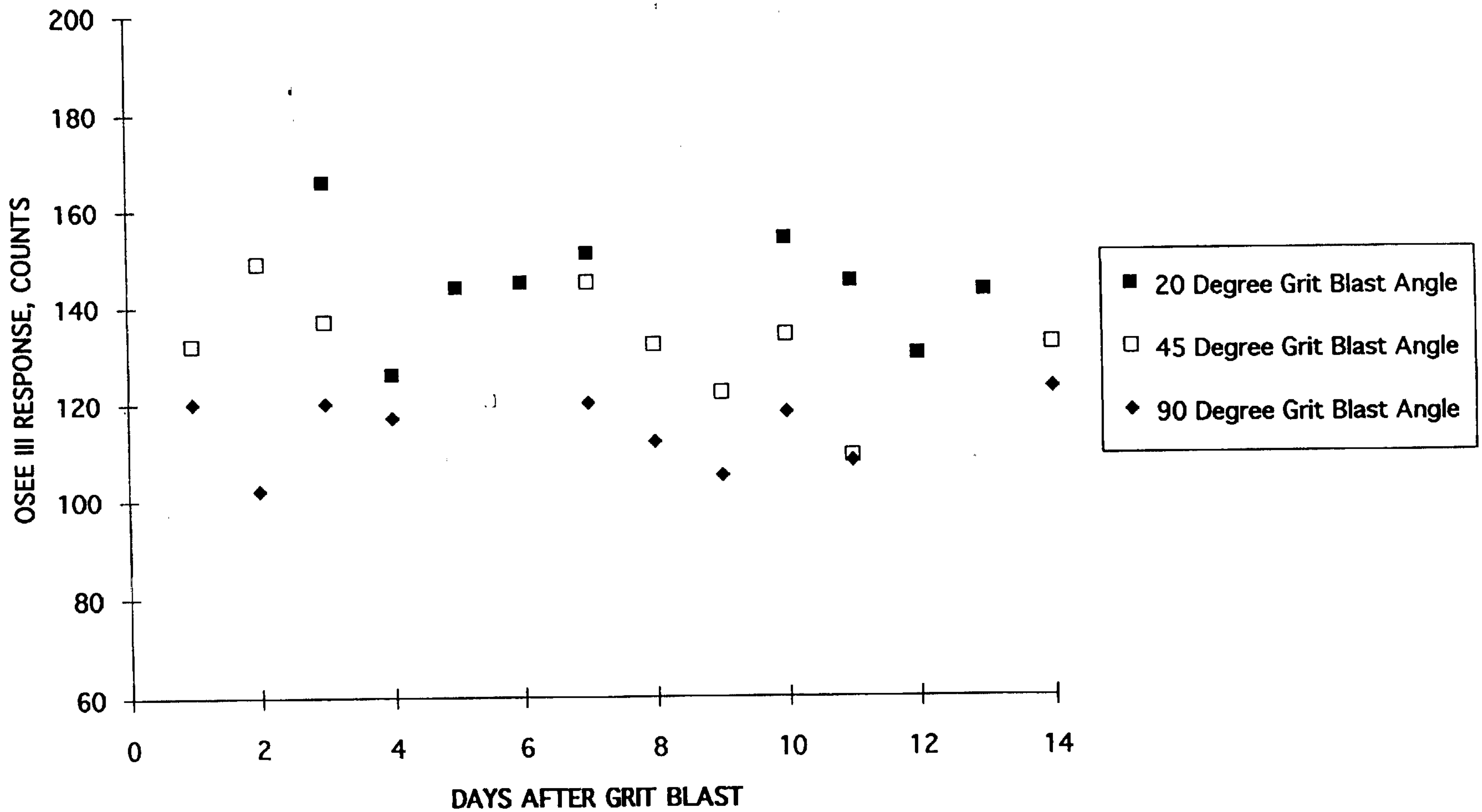
AC65q/8/95

FIGURE XXVI: EFFECT OF GRIT BLAST ANGLE ON OSEE III RESPONSE OF D6AC STEEL, 0-360 MINUTES, 6" SENSOR #4



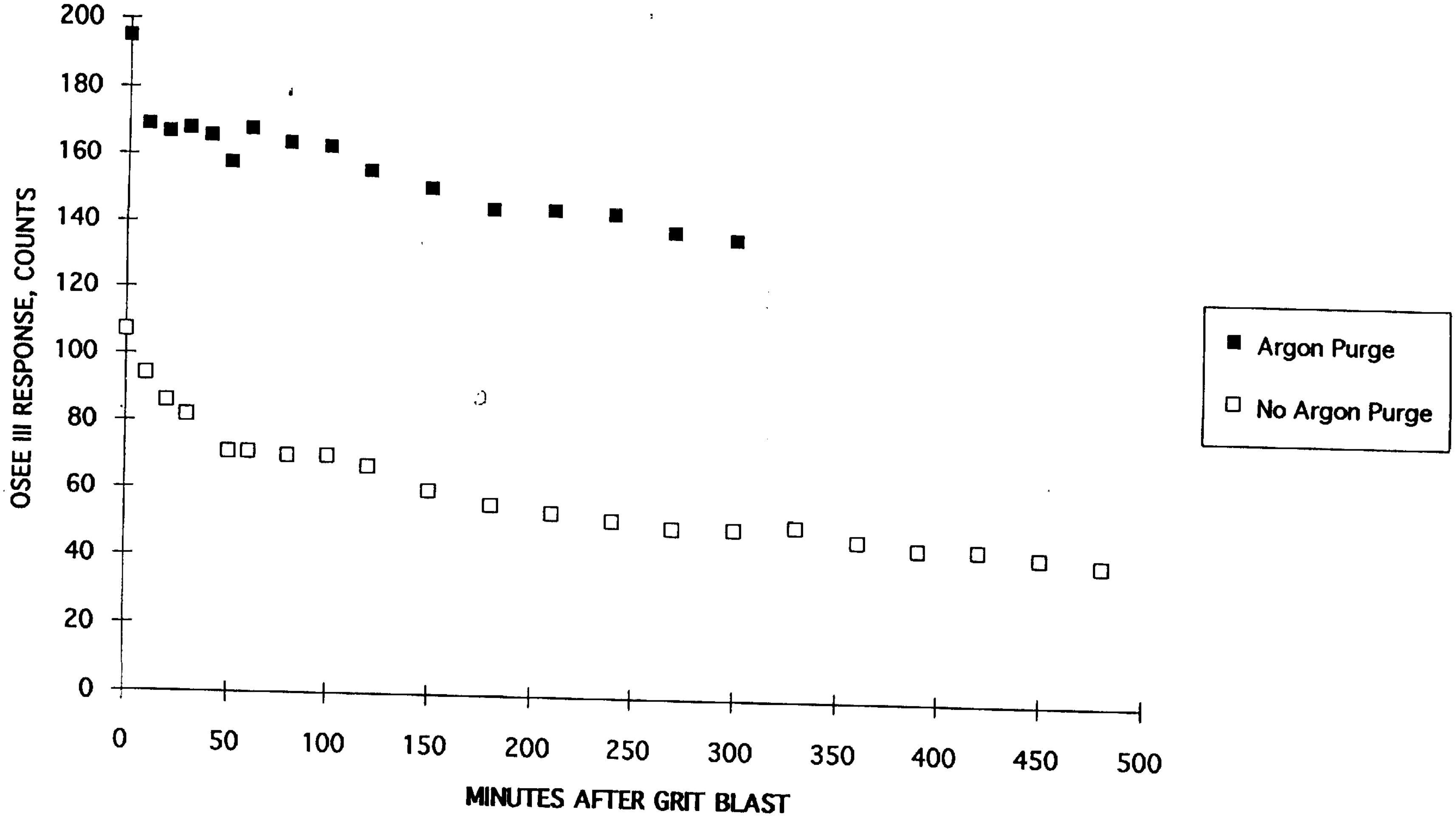
Sensor stand-off distance 1/4", scan speed 2, dwell time 0 seconds, continuous scanning mode. AC67j/9/95

FIGURE XXVII: EFFECT OF GRIT BLAST ANGLE ON OSEE III RESPONSE OF D6AC STEEL, DAYS 1-14, 6" SENSOR #4



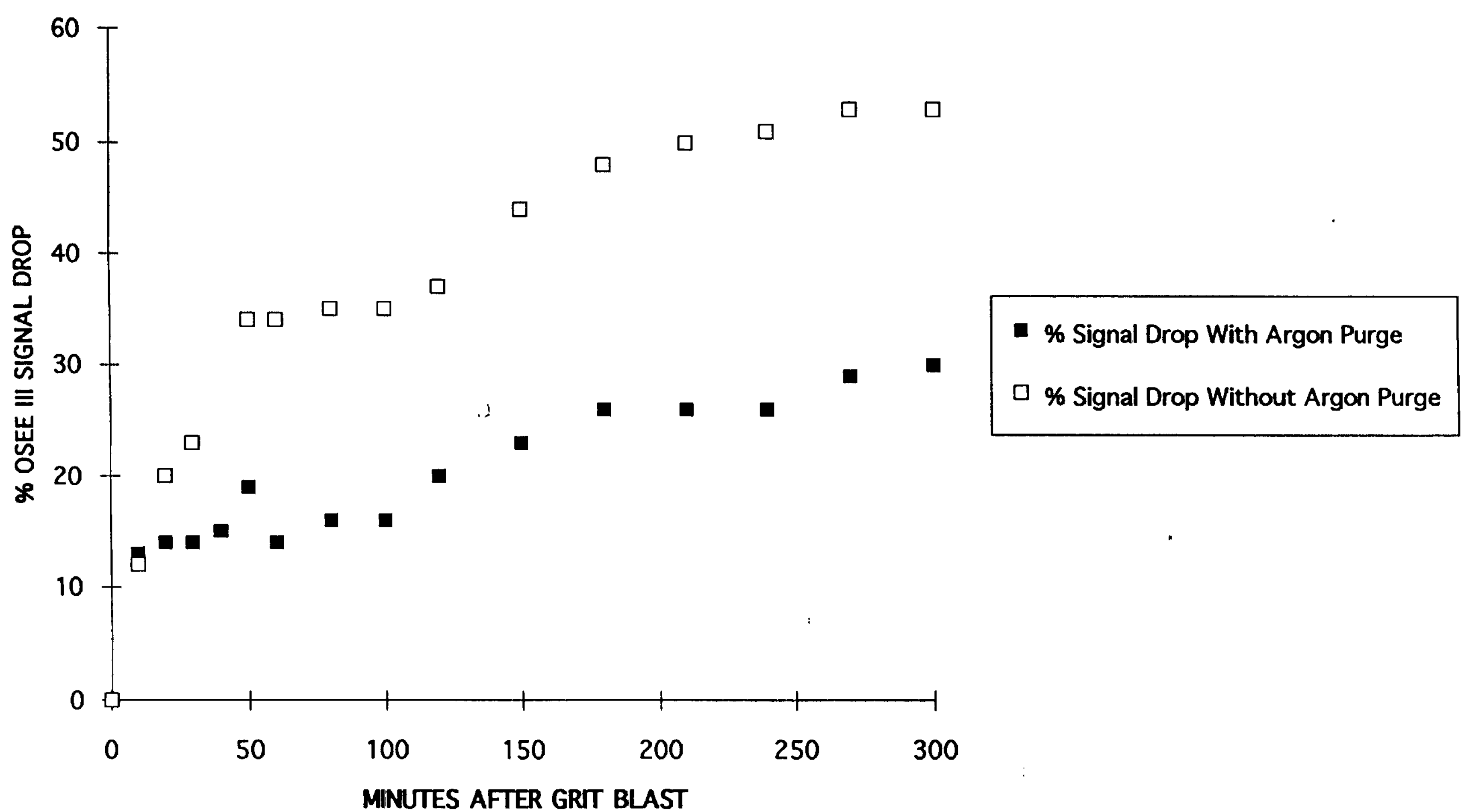
Sensor stand-off distance 1/4", scan speed 2, dwell time 0 seconds, continuous scanning mode. AC67k/9/95

FIGURE XXVIII: EFFECT OF ARGON GAS PURGE ON OSEE III RESPONSE OF GRIT BLASTED D6AC STEEL, 6" SENSOR #4, TRIAL #1



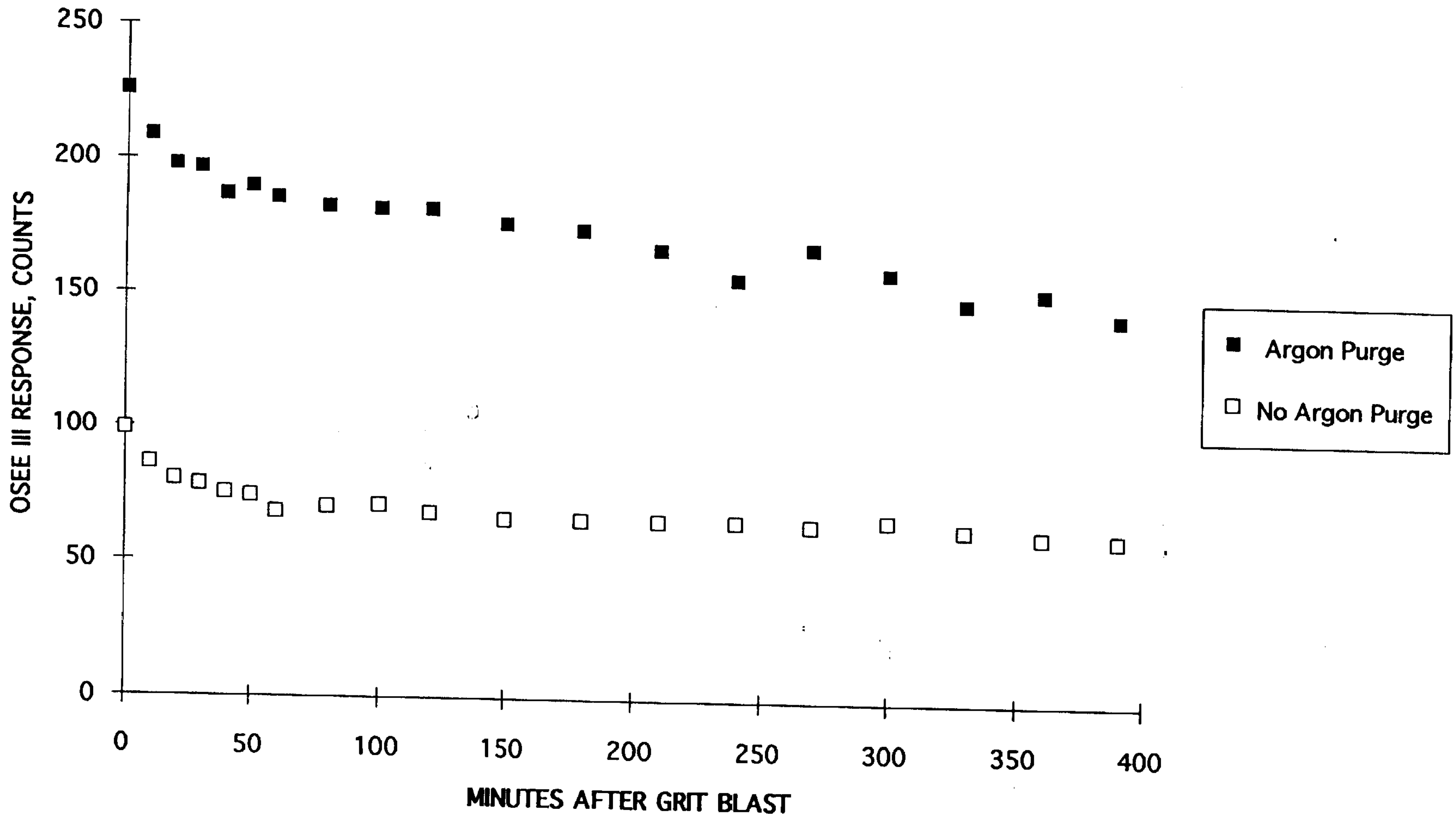
Two grit blasted (20 degrees) D6AC panels were used for the tests. Lamp voltage climbed rapidly 40 minutes into "no purge" test; unit was switched to standby for ten minutes, then the test was resumed without incident. AC67L/9/95

FIGURE XXIX: IMPACT OF ARGON PURGE ON OSEE III RESPONSE CHANGES FOR GRIT BLASTED D6AC STEEL, TRIAL #1, 6" SENSOR #4



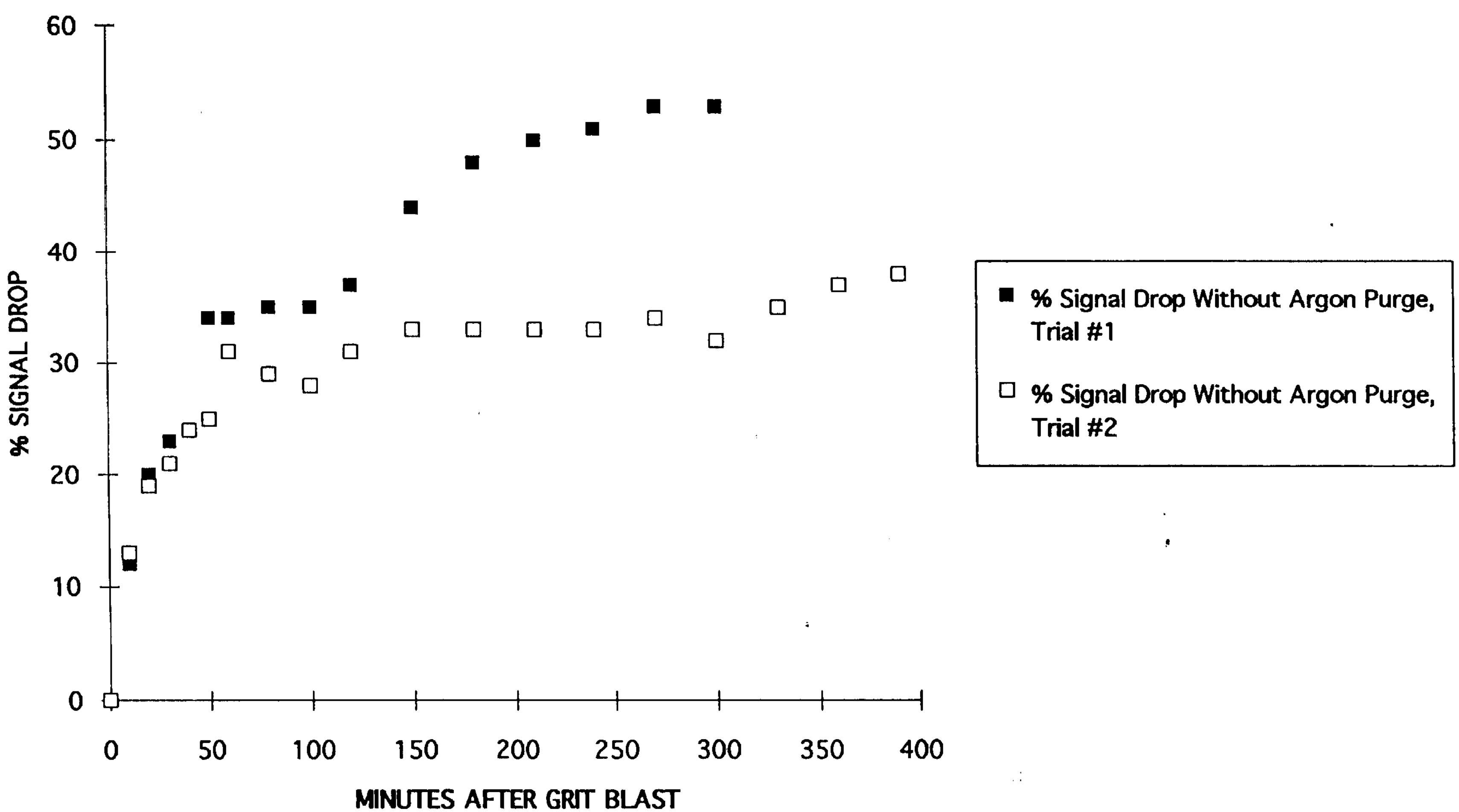
Grit blast angle 20 degrees. Two D6AC panels were used for the tests. Scan speed 2, stand-off distance 1/4", continuous scanning mode, dwell time 0 seconds. AC67m/9/95

FIGURE XXX: EFFECT OF ARGON GAS PURGE ON OSEE III RESPONSE OF GRIT BLASTED D6AC STEEL, 6" SENSOR #4, TRIAL 2



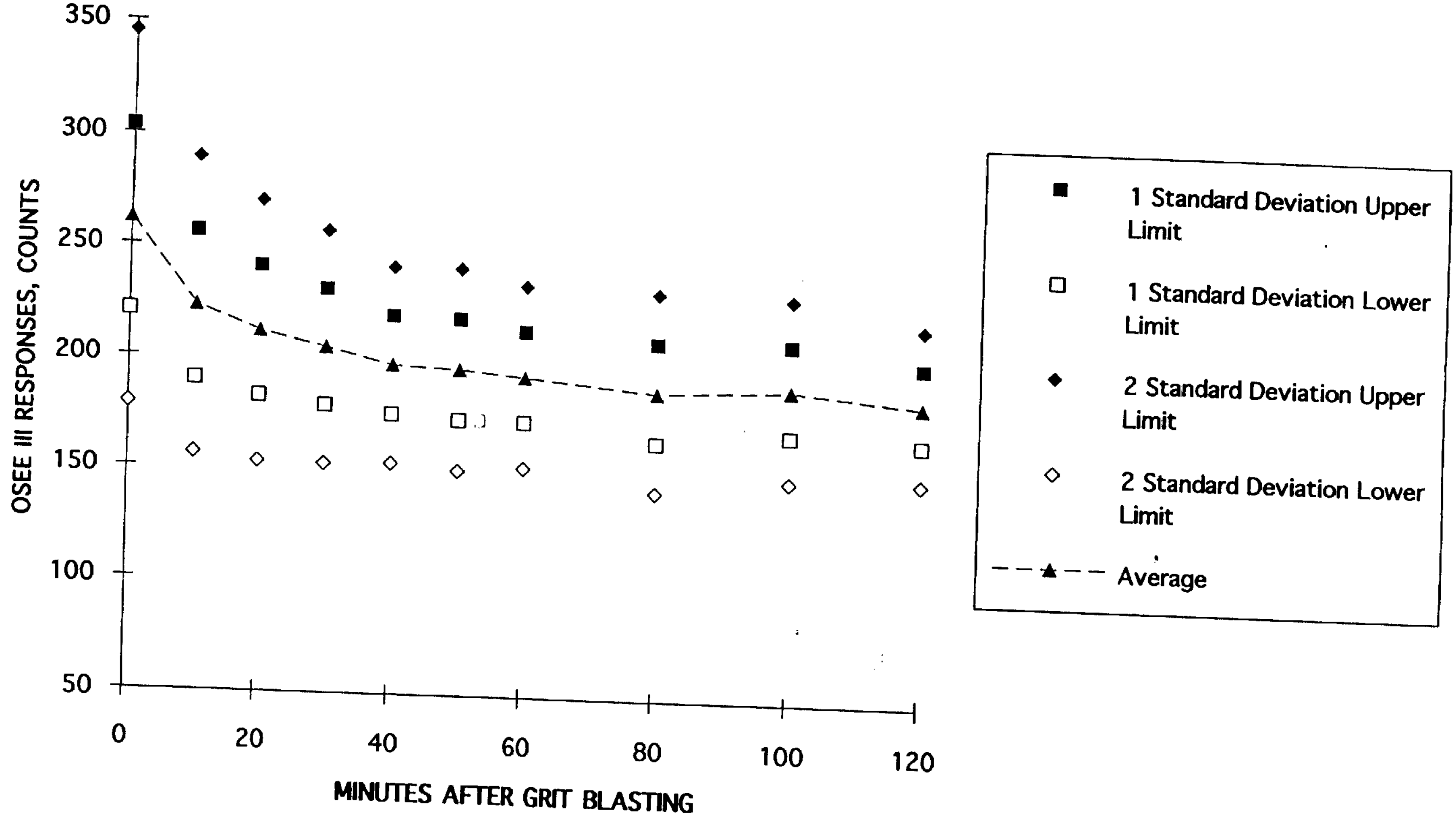
One grit blasted D6AC steel panel was used for the tests. Panel was scanned alternately with and without Ar purge. Unit was allowed to stabilize for 2 minutes after gas purge was turned on. AC67N/9/95

FIGURE XXXI: IMPACT OF ARGON GAS PURGE ON OSEE III RESPONSE CHANGES OF GRIT BLASTED D6AC STEEL, TRIALS 1 AND 2, 6" SENSOR #4



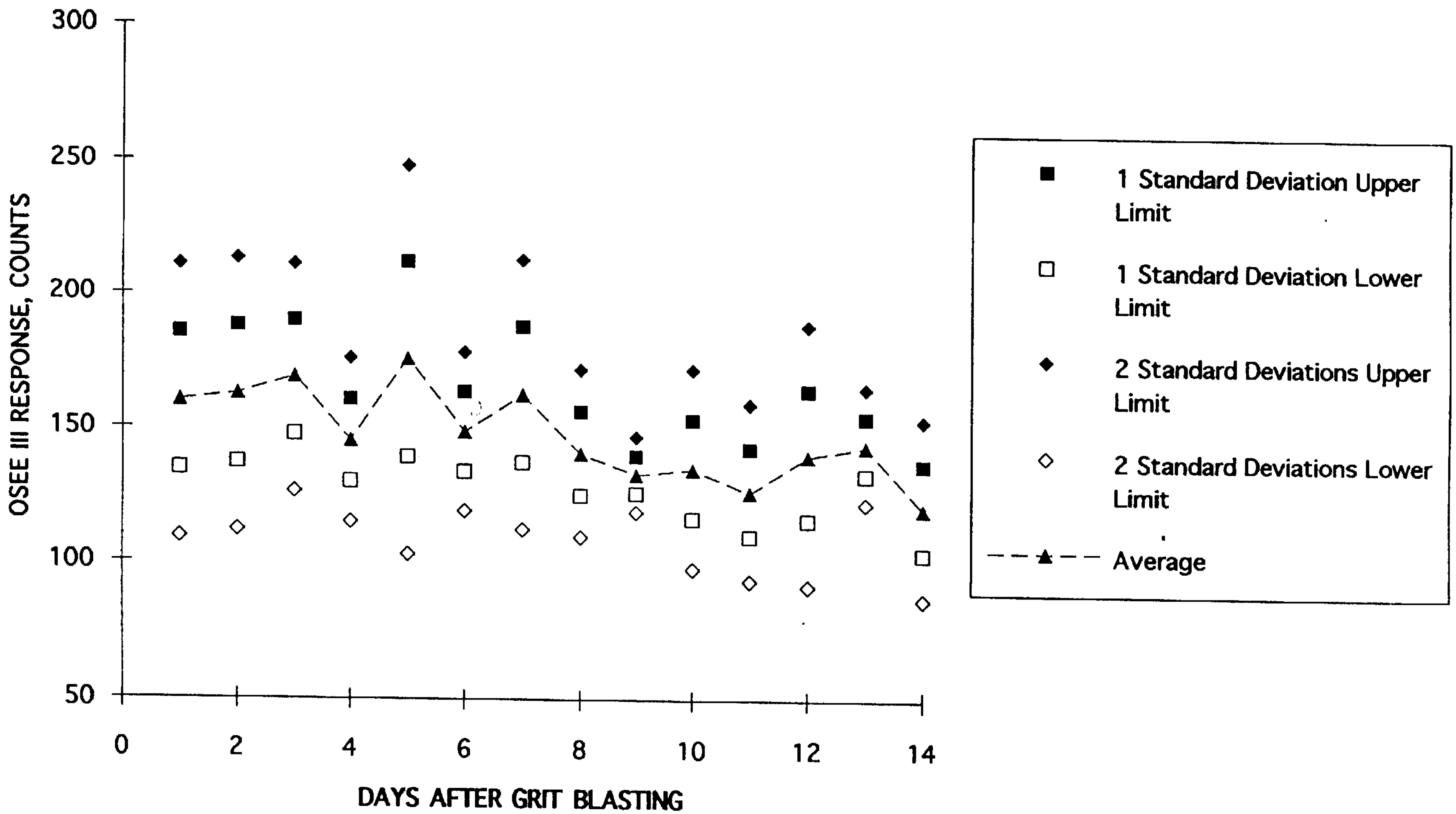
Trial #1 used 2 D6AC panels grit blasted at 20 degrees; one was scanned with argon gas purge, the other was scanned without argon purge. Trial #2 used 1 grit blasted panel which was alternately scanned with and without argon purging. AC67p/9/95

FIGURE XXXII: SUMMARY OF OSEE III RESPONSE LIMITS FOR D6AC STEEL DURING FIRST 2 HOURS AFTER GRIT BLASTING, 6" SENSOR #4



Grit blast angle 20 degrees, stand-off distance 1/4", scan speed 2, continuous scanning mode. AC68A/10/95

FIGURE XXXIII: SUMMARY OF OSEE III RESPONSE LIMITS FOR D6AC STEEL DURING 1-14 DAYS AFTER GRIT BLASTING, 6" SENSOR #4



Grit blast angle 20 degrees, stand-off distance 1/4", scan speed 2, continuous scanning mode. AC68B/10/95

TABLE I: SUMMARY OF INITIAL PSI LASER DEMO TEST RESULTS

	PSI LASER DEMO RESULTS				
Part	Contaminant	Location*	mg/ft2	PSI Location*	PSI mg/ft2
7075-T73	HD-2	54 Deg., 10-16"	20	59 Deg., 13-14"	2
	HD-2	162 Deg., 2-8"	5	172 Deg., 4-7"	1
	HD-2	305 Deg., 7-13"	1.6	313 Deg., 10-11"	0.5
	Paraffin	18 Deg., 2-8"	2.9		
	Paraffin	126 Deg., 5-11"	15.8**	133 Deg., 8-9"	1.4
	Paraffin	162 Deg.,10-16"	7.5		
	Paraffin	270 Deg., 0-6"	13	279 Deg., 4-5"	8.9
	CRC Silicone	90 Deg., 8-14"	9	97 Deg., 10-11"	5.2
	CRC Silicone	233 Deg., 3-9"	0.5***		
	CRC Silicone	305 Deg., 0-6"	8.5		
				275 Deg., 17-18"	*4.2*
D6AC	HD-2	18 Deg., 4-10"	2	22 Deg., 9-10"	1.8
	HD-2	126 Deg., 2-8"	8.4	125 Deg., 7-8"	2.5
	HD-2	270 Deg.,6-12"	14	261 Deg, 11-12"	3
				110 Deg., 10-11"	*0.5*
	Paraffin	54 Deg., 5-11"	1***		
	Paraffin	126 Deg., 10-16"	3.5		
	Paraffin	234 Deg., 3-9"	14.8**		
	Paraffin	234 Deg., 10-16"	16.4	232 Deg., 15-16"	24
	CRC Silicone	90 Deg., 11-17"	1.6***		
	CRC Silicone	198 Deg., 0-6"	7.1		
	CRC Silicone	290 Deg., 0-6"	9.9		
G. PHENOLIC	HD-2	61 Degrees	3.5	57 Degrees	5.6
	HD-2	107 Degrees	11.3	106 Degrees	10.1
	HD-2	199 Degrees	16.7	216 Degrees	14.6
	Paraffin	13 Degrees	7.6	9 Degrees	5.7
	Paraffin	37 Degrees	13.2	33 Degrees	18.4
	Paraffin	153 Degrees	17	154 Degrees	41.1
	CRC Silicone	84 Degrees	6.7		

AC57c/2/95

TABLE I: SUMMARY OF INITIAL PSI LASER DEMO TEST RESULTS

	CRC Silicone	130 Degrees	3.7***		
	CRC Silicone	222 Degrees	18.2		
*Location=Degrees rotation from "0" line, inches from top of part.					
**Gravimetric values suspect.					
***Could not be seen visually.					
	No contamination detected.				
	Results significantly different than gravimetric weight.				
No contaminants applied in these locations.					

AC57c/2/95

Table II: FT-IR Scans of Al Foils for PSI Laser Test of RSRM Parts

1. ALUMINUM - NOSE INLET HOUSING					
Contaminant	Mg/ft2	Foil#	Wave Number	No. Scans	Avg. Peak Ht.
HD-2	20	3	2925, -17	33	0.2201
	5.5	1	2925	27	0.0504
Paraffin	13	11	2917	44	0.1551
	4.3	8	2917	27	0.0871
Silicone	9	15	1257	30	0.0953
	0.3	14	1260		*
	9	15	2963	30	0.0356
	0.3	14	2960		*
2. D6AC STEEL- THROAT HOUSING					
Contaminant	Mg/ft2	Foil#	Wave Number	No. Scans	Avg. Value
HD-2	14.2	6	2925	33	0.196
	1.9	4	2925	32	0.0253
Paraffin	16.4	10	2917	52	0.3723
	3.1	11	2917	27	0.0198
Silicone	9.7	18	1257	30	0.0881
	1.6	16	1273, -50	27	*
	9.7	18	2963	30	0.0376
	1.6	16	2940, -63	36	*
3. GLASS PHENOLIC - FORWARD NOSE RING					
Contaminant	Mg/ft2	Foil#	Wave Number	No. Scans	Avg. Value
HD-2	16.7	3	2925	33	0.1006
	3.5	1	2925, -40	45	0.0398
Paraffin	16.5	9	2917	33	0.341
	7.6	7	2917	27	0.0916
Silicone	18.2	6	1265, -57	33	0.1421
	3.7	5	1265	27	*
	18.2	6	2963	33	0.1056
	3.7	5	2963	27	*

*Peaks were too low to be detected. 64 aquisitions per scan, 32X lens, 16 cm-1 resolution, -1 X % reflectance data conversion. AC55c/12/94

TABLE III

FT-IR ANALYSIS OF METALLIC RSRM NOZZLE PART WITNESS PANELS

1. Nose Inlet Housing (Aluminum)

Contaminant	Avg. Peak Hts. Pre-laser test	Avg. Peak Hts. Post-laser test
HD-2	.045	.050
Paraffin	.014	.013
Silicone (1260 cm^{-1})	.060	.057
Silicone (2960 cm^{-1})	.034	.032

2. Throat Housing (D6AC Steel)

Contaminant	Avg. Peak Hts. Pre-laser Test	Avg. Peak Hts. Post-laser test
HD-2	.017	.010
Paraffin	.018	.016
Silicone (1260 cm^{-1})	.021	.010
Silicone (2960 cm^{-1})	.004	.004

Data are average peak heights across the witness panel surfaces. For HD-2 grease the CH_2 peak at 2925 cm^{-1} was measured, and the CH_2 peak at 2917 was measured for paraffin.
32X lens, 16 cm-1 resolution, 64 scans per acquisition, log 1/R data conversion.
AC55h/12/94

TABLE IV

FT-IR RESULTS-METALLIC RSRM WITNESS PANELS				
1. Nose Inlet Housing (Aluminum)				
Contaminant	Avg Peak Hts. Pre-Laser Test	Avg Peak Hts. Post-laser Test	% Difference	Avg % Diff from Contam. Step Plates
HD-2	0.045	0.05	10%	20%
Paraffin	0.014	0.013	7%	15%
Silicone-1260	0.06	0.057	5%	25%
Silicone-2960	0.034	0.032	6%	13%
2. Throat Housing (D6AC Steel)				
Contaminant	Avg Peak Hts. Pre-laser Test	Avg Peak Hts. Post-Laser Test	% Difference	Avg % Diff. from Contam. Step Plates
HD-2	0.017	0.01	41%	30%
Paraffin	0.018	0.016	11%	16%
Silicone-1260	0.021	0.01	52%*	16%
Silicone-2960	0.004	0.004	0%	20%

Footnote: Data are average peak heights across the witness panel surfaces.
For HD-2 grease, the CH2 peak at 2925 cm-1 was measured.
For Paraffin, the CH2 peak at 2917 cm-1 was measured.
A 32X objective lens was used, with 16 cm-1 Resolution, 64 scans per acquisition.
* Baseline correction in this region of spectrum was unsuccessful, which lead to significant scatter in the results.

TABLE V

NIR RESULTS-GLASS PHENOLIC RSRM WITNESS PANELS

Contaminant	October 94 Prediction	November 94 Prediction	Gravimetric Coating Level
HD-2 Grease	16.3 mg/ft^2	15.8 mg/ft^2	16.1 mg/ft^2
CRC Silicone	6.5 mg/ft^2	7.2 mg/ft^2	5.5 mg/ft^2
Paraffin Wax	32.1 mg/ft^2	30.5 mg/ft^2	----

A calibration set of NIR optical fiber data was developed using six known levels of contamination on both carbon phenolic and glass phenolic plates. The data from the carbon phenolic was not as consistent as the glass phenolic. The calibration set for glass phenolic was used to predict the level of contamination on witness panels contaminated along with the forward nose ring used for the PSI demonstration. Carbon phenolic was not used in the PSI eximer laser UVF demonstration, and therefore predictions of unknown for carbon phenolic plates were not performed.

Predictions were performed prior to (October 94) and following (November 94) the PSI laser demonstration, in an effort to determine the stability of the contamination.

The predictions for paraffin were extrapolated, since contamination step plates used to model the contaminant were coated only to levels of approximately 25 mg/ft^2. No gravimetric data were obtained for the paraffin witness panel, because it was contaminated separately from the forward nose ring.

AC56c/1/95

TABLE VI
SUMMARY OF UVF ALUMINUM/HD-2 GREASE CALIBRATION DATA

Standard	HD-2 Level, mg/ft^2	UVF Signal Counts	Least Squares Prediction
PSI	1	702	1452
	2	1848	2442
	5	5638	5412
	10	12519	10362
	20	19224	20261
MSFC	3	3000	3632
	6	6743	5583
	10	8030	8184
	14	10200	10785
	22	16200	15987

50 pulses, 2 second scan time. Gain setting 4.5.
PSI standard was a smooth aluminum panel, approximately 10" X 14", coated with 5 levels of HD- grease in 2-inch diameter circles.
MSFC standards were grit blasted (20 degrees) aluminum panels, approximately 6" X 6" square, coated with 1 level of grease per panel.

AC61i/5/95

TABLE VII
RESULTS FROM UVF CONTAMINATION SYSTEM ANALYSIS OF HD-2 COATINGS ON ALUMINUM NOSE INLET HOUSING

New HD-2 Grease Coatings

HD-2 Actual Location	Grav. Coating Level, mg/ft²	Predicted Location	Predicted Coating Level, mg/ft²
40°, 2" from top	4.3	44°, 3" from top	4-5
60°, 4" from top	19.3	66°, 5" from top	16-17
180°, 12" from top	12.6	180°, 11" from top	5-7
200°, 4" from top	6.7	200°, 6" from top	5-7
280°, 11" from top	8.9	272°, 14" from top	5-7
335°,.6" from top	20-22	330°, 6" from top	7-9
335, 13" from top	2.7	330°, 14" from top	2-3

Original HD-2 Grease Coatings

HD-2 Actual Location	Grav. Coating Level, mg/ft²	Predicted Location	Predicted Coating Level, mg/ft²
54°, 13" from top	20.0	52°, 12" from top	1-2
162°, 4" from top	5.0	Not Detected	—
305°, 11" from top	1.6	313°, 12" from top	1-1.5

1 Gravimetric coating levels determined by measuring weight changes of aluminum foil witness samples coated in parallel with nose inlet housing.
2 Nose inlet housing was analyzed as follows: 25 laser pulses per location with a 2 second scan time, 18 rotational positions of 20 degrees, two vertical robot head positions of 36" and 45" to center of camera.
3 Data analysis was performed with 25% clipping of actual images.
4 Robot turntable was manually controlled for these tests.
5 HD-2 coatings were mapped according to rotational degrees marked on the nose inlet housing, and distance of coating from the top of the housing.

AC64c/7/95

TABLE VIII
GRAVIMETRIC RESULTS FROM NIR TAPE RESIDUE STUDIES

Matl, plate #	Tape	Boat Wt. Initial, g	Boat Wt. Final, g	Resid. Wt., g[1]	Minus Baseline[2]	Coating Level[3], mg/ft^2
7075-T73, plate 80	Bonding	.99133	.99338	.00205	.00153	10.9
7075-T73, plate 66	Grit Blast	.99554	.99651	.00097	.00045	3.2
7075-T73, plate 76	Masking	.99610	.99833	.00223	.00171	12.1
7075-T73, plate 52	Yellow Vinyl	1.00166	1.00350	.00184	.00132	9.4
7075-T73, plate 82	None	.99020	.99072	.00052	NA	NA
D6AC, plate 27	Masking	.99274	.99470	.00196	.00115	8.2
D6AC, plate 12	Grit Blast	.98917	.99032	.00115	.00034	2.4
D6AC, plate 6	Bonding	.98959	.99213	.00254	.00173	12.2
D6AC, plate 34	Yellow Vinyl	.99497	.99780	.00283	.00202	14.3
D6AC, plate 19	None	.99569	.99650	.00081	NA	NA

[1] Residues were collected by immersing the panels in approximately 1500 ml methyl chloroform in 4L beakers, agitating the beakers in an ultrasonic bath for 10 minutes, then evaporating the solvent.
[2] Baseline residue weights of .0005 or .0008 grams for panels that did not have tape applied were subtracted from total residue weights.
[3] Test panels were 4.5 X 4.5 inches in size, so a multiplication factor of 7.1 was used to convert coating weights to coverage in mg/ft^2.

AC60ab/4/95

TABLE IX
OSEE II ANALYSIS OF D6AC STEEL AND 7075-T73 ALUMINUM PANELS USED FOR NIR TAPE RESIDUE STUDIES

Matl, plate #	Init. OSEE, cV[1,2,3]	Tape[4]	OSEE After Tape Removed, cV[1,3]	% Signal Change	OSEE After Cleaning[1,3]	% From Initial
7075-T73, plate 76	1980 (46)	Masking	1452 (170)	-27	1844 (59)	-7
7075-T73, plate 52	1966 (47)	Yellow Vinyl	1668 (32)	-15	1684 (63)	-14
7075-T73, plate 66	1977 (29)	Grit Blast	1488 (88)	-25	1842 (28)	-7
7075-T73, plate 80	1972 (48)	Bonding	1489 (55)	-24	1893 (42)	-4
7075-T73, plate 82	1974 (34)	None	1841[5] (42)	-7[5]	1869 (33)	-5
D6AC, plate 27	694 (27)	Masking	589 (21)	-15	534 (17)	-23
D6AC, plate 12	687 (64)	Grit Blast	426 (57)	-40	385 (28)	-43
D6AC, plate 6	667 (22)	Bonding	588 (41)	-12	571 (27)	-14
D6AC, plate 34	713 (37)	Yellow Vinyl	799 (18)	+12	579 (16)	-19
D6AC, plate 19	752 (40)	None	662[5] (53)	-12[5]	517 (10)	-31

1 Numbers in parentheses are standard deviation.

2 Panels were grit blasted, then vapor degreased with methyl chloroform immediately prior to initial OSEE II measurements.

3 OSEE standoff distance was 1/4" for D6AC steel , and 1/8" for 7075-T73 aluminum.

4 Tapes were applied with hand pressure. Samples were kept at laboratory conditions for 10 days before tapes were removed.

5 No tapes were applied to this panel, it was used as the baseline.

AC60bb/4/95

TABLE X
OSEE II ANALYSIS OF NIR TAPE RESIDUE CALIBRATION STANDARDS

7075-T73 Plate #	Init. OSEE, cV	Tape Adhesive	Coating Level, mg/ft²	Final OSEE, cV	% OSEE Init. cV
76	1868 (114)	Masking	5.4	1166 (187)	62
			9.1	854 (75)	46
			13.7	555 (34)	29
			18.9	474 (23)	25
80	1911 (59)	Bonding	4.2	1505 (91)	79
			10.1	1308 (99)	68
			14.4	990 (58)	52
			19.8	896 (34)	47
52	1657 (49)	Yellow Vinyl	3.8	1285 (50)	78
			9.3	1114 (73)	67
			15.1	987 (89)	60
			20.6	861 (61)	52
66	1864 (83)	Grit Blast	3.3	1010 (104)	54
			9.0	632 (139)	34
			14.6	500 (97)	27
			18.8	438 (38)	23

D6AC Plate #	Init. OSEE, cV	Tape Adhesive	Coating Level, mg/ft²	Final OSEE, cV	% OSEE Init. cV
12	448 (33)	Grit Blast	4.4	126 (7)	28
			9.0	169 (10)	38
			14.1	243 (8)	54
			19.6	265 (11)	59
6	486 (21)	Bonding	4.2	593 (45)	122
			10.9	703 (20)	145
			14.4	598 (63)	123
			19.5	672 (37)	138
27	484 (25)	Masking	5.0	289 (17)	60
			9.2	273 (9)	56
			14.4	259 (9)	54
			19.0	256 (9)	53
34	547 (11)	Yellow Vinyl	4.4	568 (15)	104
			10.7	600 (18)	109
			14.1	528 (28)	97
			19.7	557 (23)	102

[1] Calibration standards prepared by extracting adhesives from tapes with methyl chloroform, then spray applying the mixtures using a Graco air brush (model G1265, series B). Coating levels determined by measuring weight changes of aluminum foil witness samples sprayed along with the steel or aluminum panels.
[2] OSEE II standoff distance was 1/4" for D6AC steel and 1/8" for 7075-T73 aluminum. AC61b/5/95

TABLE XI
OSEE II ANALYSIS OF D6AC STEEL PANELS CONTAMINATED WITH RSRM TAPE ADHESIVES

Trial	Plate #	Init. OSEE, cV	Tape	OSEE After Tape Removed	% Signal Change
1	27	694 (27)	Masking	589 (21)	-15
1	12	687 (64)	Grit Blast	426 (57)	-40
1	6	667 (22)	Bonding	588 (41)	-12
1	34	713 (37)	Yellow Vinyl	799 (18)	+12
1	19	752 (40)	None	662 (53)	-31
2	27	825 (38)	Grit Blast	345 (19)	-58
2	34	850 (25)	Yellow Vinyl	778 (18)	-8
2	19	772 (45)	Bonding	661 (10)	-14
2	6	746 (58)	None	595 (46)	-20

1 Numbers in parentheses are standard deviation.

2 Panels were grit blasted, then vapor degreased with methyl chloroform immediately prior to initial OSEE II measurements.

3 OSEE standoff distance was 1/4".

4 Tapes were applied with hand pressure. Samples were kept at laboratory conditions for 10 days before tapes were removed.

5 Masking tape was not repeated.

AC62 m/6/95

TABLE XII
OSEE II ANALYSIS OF D6AC STEEL AND 7075-T73 ALUMINUM PANELS USED FOR NIR TAPE RESIDUE STUDIES

Material, plate #	Init. OSEE, cV[1,2,3]	Tape[4]	OSEE After Tape Removed, cV[1,3]	% Signal Change	Est. mg/ft² From Cal. Data[6]
7075-T73, plate 76	1980 (46)	Masking	1452 (170)	-27	3-5
7075-T73, plate 52	1966 (47)	Yellow Vinyl	1668 (32)	-15	2-4
7075-T73, plate 66	1977 (29)	Grit Blast	1488 (88)	-25	1-3
7075-T73, plate 80	1972 (48)	Bonding	1489 (55)	-24	7-9
7075-T73, plate 82	1974 (34)	None	1841[5] (42)	-7[5]	NA
D6AC, plate 27	694 (27)	Masking	589 (21)	-15	2-4
D6AC, plate 12	687 (64)	Grit Blast	426 (57)	-40	2-4
D6AC, plate 6	667 (22)	Bonding	588 (41)	-12	ND[7]
D6AC, plate 34	713 (37)	Yellow Vinyl	799 (18)	+12	ND[7]
D6AC, plate 19	752 (40)	None	662[5] (53)	-12[5]	NA

1 Numbers in parentheses are standard deviation.

2 Panels were grit blasted, then vapor degreased with methyl chloroform immediately prior to initial OSEE II measurements.

3 OSEE standoff distance was 1/4" for D6AC steel , and 1/8" for 7075-T73 aluminum.

4 Tapes were applied with hand pressure. Samples were kept at laboratory conditions for 10 days before tapes were removed.

5 No tapes were applied to this panel, it was used as the baseline.

6 See calibration data Table AC61b/5/95, and Figures AC61c/5/95 and AC61d/5/95.

7 Not determined for this panel, because OSEE II responses did not change significantly as increasing levels of adhesive were applied.

AC61a/5/95

TABLE XIII
SUMMARY OF D6AC STEEL AND 7075-T73 ALUMINUM TAPE RESIDUE STUDY RESULTS

Matl., Plate #	Tape[1]	Est. mg/ft² OSEEII[2]	Est. mg/ft² FT-IR[3]	Est. mg/ft² NIR[4]	Est. mg/ft² Gravimet.[5]	NIR mg/ft² Post Clean[6]	NIR mg/ft² Removed[7]
7075-T73, 76	Masking	3-5	<14	14.1	12.1	4.8	9.3
7075-T73, 52	Yellow Vinyl	2-4	<15	8.7	9.4	1.6	7.1
7075-T73, 66	Grit Blast	1-3	<15	8.8	3.2	2.8	6.0
7075-T73, 80	Bonding	7-9	<20	11.2	10.9	3.9	7.3
D6AC, 27	Masking	2-4	<15	14.8	8.2	5.1	9.7
D6AC, 12	Grit Blast	2-4	<20	17.5	2.4	11.4	6.1
D6AC, 34	Yellow Vinyl	ND[8]	<20	12.7	14.3	4.8	7.9
D6AC, 6	Bonding	ND[8]	<20	18.5	12.2	5.0	13.5

[1] Tapes were applied with hand pressure. Samples were kept at laboratory conditions for 10 days before tapes were removed.

[2] Estimates made for test panels immediately after tape removal. Estimates based on analyses of calibration standards; see Table AC61b/5/95 and Figures AC61c/5/95 and AC61d/5/95.

[3] Measurements made immediately after tape removal. Estimates based on analyses of calibration standards used to develop predictive models for the NIR system.

[4] Measurements made immediately after tape removal. Based on analyses of calibration standards containing 0-25 mg/ft² levels of tape adhesives.

[5] Residues were collected by immersing the panels in beakers containing 1500 ml methyl chloroform, agitating the beakers in an ultrasonic bath for ten minutes, then evaporating the solvent.

[6] Estimate of tape residue remaining on surface after cleaning with methyl chloroform.

[7] Estimated quantity of tape residue removed by the cleaning process.

[8] Not determined for this panel, because OSEE II responses did not change significantly as increasing levels of adhesives were applied.

AC61e/5/95

TABLE XIV: SUMMARY OF OSEE II ANALYSIS RESULTS FROM ENVIRONMENTAL EXPOSURE STUDIES WITH GRIT BLASTED LiAl

Target Temp. Fahrenheit	Actual Temp. Fahrenheit	Target RH%	Actual RH%	Abs. Moisture PPM	Initial OSEE Centivolts	Final OSEE Centivolts	Delta OSEE Centivolts	% Drop
60	58	20	22	3409	1898	1485*	413	22
60	58	50	49	7954	1760	1252	508	29
60	59	70	66	10909	1992	1257	735	37
75	73	20	32	8863	1814	1562	252	14
75	73	50	47	12727	1870	1460*	410	22
75	73	70	65	17727	1864	1186	678	36
90	88	20	27	11818	1844	1602	242	13
90	88	50	46	20454	1882	1523	359	19
90	88	70	58	25909	1543	1046	497	32

*Extrapolated data.

In general, the environmental chamber achieved equilibrium temperature and humidity values within 0-10 minutes after initiating tests. The one exception was 60F/50% RH, which required 60 minutes.

Grit blast angle 20 degrees, stand-off distance 1/4".

AC67E/9/95

TABLE XV: SUMMARY OF LiAl OSEE II DATA USED TO PERFORM STATISTICAL ANALYSES

Observation Order	*Temperature, F*	*RH, %*	*Line Slope, cV/min.*	*Y-Intercept, cV*	*Delta OSEE, cV*
1	58	22	-0.04	1704	413
2	58	49	-0.0188	1392	508
3	59	66	-0.0444	1527	735
4	73	32	-0.028	1724	252
5	73	47	-0.03	1639	410
6	73	65	-0.0497	1539	678
7	88	27	-0.021	1726	242
8	88	46	-0.034	1757	359
9	88	58	-0.031	1240	497

TABLE XVI: SUMMARY OF LINEAR REGRESSION ANALYSIS DATA FROM OSEE II SCANS OF GRIT BLASTED LiAl

Temperature Degrees F	*Relative Humidity Percent*	*Line Slope cV per Minute*	*Y-Axis Intercept Centivolts*	*R Square*	*Adj. R Square*
60	20	-0.04	1704	0.833	0.832
60	50	-0.018	1391	0.502	0.498
60	70	-0.044	1527	0.73	0.728
75	20	-0.028	1724	0.915	0.914
75	50	-0.03	1638	0.802	0.8
75	70	-0.049	1539	0.834	0.833
90	20	-0.021	1726	0.793	0.792
90	50	-0.034	1758	0.914	0.914
90	70	-0.031	1240	0.762	0.76

Statistical analyses performed with Excel software, version 4.0. AC69a/12/95

TABLE XVII: SUMMARY OF LiAl STATISTICAL ANALYSIS RESULTS

Response	Observation Number	Temperature Degrees F	RH, %	Actual Value	Predicted Value	Residual
Slope	1	58	22	-0.04	-0.0289	-0.0112
	2	58	49	-0.0188	-0.0365	0.0177
	3	59	66	-0.0444	-0.0412	-0.0032
	4	73	32	-0.028	-0.029	0.001
	5	73	47	-0.03	-0.0333	0.003
	6	73	65	-0.0497	-0.0385	-0.0112
	7	88	27	-0.021	-0.0249	0.004
	8	88	46	-0.034	-0.0304	-0.004
	9	88	58	-0.031	-0.0338	0.003
Y-Intercept	1	58	22	1704	1736	-32
	2	58	49	1392	1549	-157
	3	59	66	1527	1433	94
	4	73	32	1724	1678	46
	5	73	47	1639	1574	65
	6	73	65	1539	1450	89
	7	88	27	1726	1723	3
	8	88	46	1757	1592	165
	9	88	58	1240	1509	-269
Delta OSEE II	1	58	22	413	332	81
	2	58	49	508	569	-61
	3	59	66	735	712	23
	4	73	32	252	335	-83
	5	73	47	410	466	-56
	6	73	65	678	624	54
	7	88	27	242	206	36
	8	88	46	359	373	-14
	9	88	58	497	478	19

Statistical analyses performed with Design-Expert software, version 4.0.2. AC68Q/10/95

TABLE XVIII
OSEE III RESPONSES OF D6AC STEEL FOR TWO HOURS AFTER GRIT BLAST, SENSOR #4

Trial #5

Time	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Average
0	243	258	248	250	265	270	256
10	207	214	201	202	213	218	209
20	182	183	171	175	185	191	181
30	179	185	177	182	196	200	187
40	182	185	176	179	192	197	185
50	188	193	182	185	197	205	192
60*	159	162	151	157	162	160	159
80	159	162	153	156	155	137	154
100	156	159	149	150	143	121	146
120	150	155	144	144	139	117	142
	Δ=93*	Δ=103*	Δ=104*	Δ=106*	Δ=126*	Δ=153*	Δ=114*

Temperature 76°F, RH 43%

Trial #6

Time	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Average
0	281	299	284	287	281	265	282
20	219	225	209	213	213	209	214
30	220	225	209	211	211	205	214
40	219	224	208	211	210	205	213
50	219	225	208	210	210	205	213
60	208	213	198	200	203	202	204
80	225	230	211	212	212	207	216
100	229	238	221	222	222	215	224
120	211	215	197	200	199	192	202
	Δ=70	Δ=84	Δ=87	Δ=87	Δ=82	Δ=73	Δ=80

Temperature 78°F, RH 45%

Trial #7

Time	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Average
0	253	264	252	257	264	257	258
10	230	243	230	230	234	229	233
20	210	219	208	209	214	207	211
30	200	209	200	205	207	199	203
40	196	204	195	198	202	195	198
50	202	211	199	203	206	197	203
60	192	201	192	197	200	195	196
80	188	195	183	188	191	184	188

100	194	201	189	192	196	187	193
120	190	198	185	187	192	184	189
	Δ=63	Δ=66	Δ=67	Δ=70	Δ=72	Δ=73	Δ=69

Temperature 77°F, RH 45%

Trial #8

Time	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Average
0	219	227	216	221	231	209	221
10	195	203	191	193	203	184	195
20	189	195	181	185	192	174	186
30	182	187	174	173	181	163	177
40	183	185	175	177	184	169	179
50	176	182	172	176	182	165	176
60	177	178	167	167	175	158	170
80	174	179	168	168	177	158	171
100	180	185	172	175	181	159	175
120	181	187	174	176	184	164	178
	Δ=38	Δ=40	Δ=42	Δ=45	Δ=47	Δ=45	Δ=43

Temperature 77°F, RH 47%

Trial #9

Time	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Average
0	263	276	268	269	276	269	270
10	239	252	244	246	251	245	246
20	227	240	231	235	241	234	235
30	214	228	223	230	233	228	226
40	208	224	215	224	221	213	218
50	207	216	207	213	217	211	212
60	205	219	213	219	221	214	215
80	205	219	210	213	219	214	213
100	200	211	204	207	214	206	207
120	192	201	195	204	209	203	201
	Δ=71	Δ=75	Δ=73	Δ=65	Δ=67	Δ=66	Δ=69

Temperature 77°F, RH 43%

Trial #10

Time	Chan 1	Chan 2	Chan 3	Chan 4	Chan 5	Chan 6	Average
0	263	281	273	270	272	269	271
5	228	241	234	231	237	235	234
10	218	223	218	218	224	222	221
20	206	215	208	210	215	213	211
30	196	205	197	198	206	206	201
40	182	188	181	186	191	190	186
50	189	199	193	198	206	203	198
60	191	198	191	192	196	191	193

80	174	181	175	181	189	188	181
100	181	192	186	192	198	195	191
120	177	185	176	182	189	187	183
	Δ=86	**Δ=96**	**Δ=97**	**Δ=88**	**Δ=83**	**Δ=82**	**Δ=88**

Temperature 77°F, RH 41%

Time: minutes after grit blast.
All measurements are in signal counts.
Grit blast angle 20 degrees. Stand-off distance 1/4".
Scan rate 2, 0 second delay, continuous scanning mode.
Δ: Initial reading minus final reading.
* Argon purge failed at 60 minutes and tank had to be replaced. Readings were lower when lamp was restarted, which resulted in anomalously high signal drops for this time period.
AC62d/6/95

TABLE XIX: EFFECT OF SENSOR STAND-OFF DISTANCE ON OSEE III RESPONSE OF D6AC STEEL, SENSOR #4

Stand-Off	*Ch 1*	*Ch 2*	*Ch 3*	*Ch 4*	*Ch 5*	*Ch 6*	*Mean*
0.2	96	105	113	114	123	128	113
0.2	92	100	108	109	117	124	108
0.2	92	100	109	108	118	123	108
0.21	88	96	103	105	115	120	105
0.21	89	95	103	102	112	116	103
0.21	89	95	103	104	113	119	104
0.22	86	92	101	103	114	119	102
0.22	85	90	98	99	109	112	99
0.22	88	94	102	101	111	116	102
0.23	79	85	94	93	104	110	94
0.23	80	85	95	95	105	110	95
0.23	81	86	95	94	105	111	96
0.24	47	48	52	52	59	63	54
0.24	78	82	90	91	101	106	91
0.24	77	82	92	93	103	110	93
0.25	74	77	85	86	96	101	86
0.25	70	74	80	81	90	95	82
0.25	72	76	84	84	94	99	85
0.26	66	71	79	81	90	97	81
0.26	68	71	78	81	91	96	81
0.26	69	73	81	82	90	86	80
0.27	70	72	79	80	90	95	81
0.27	70	75	84	85	93	97	84
0.27	73	79	87	87	96	100	87
0.28	71	74	82	83	92	97	83
0.28	70	73	79	80	90	94	81
0.28	71	75	81	81	91	97	83
0.29	69	73	80	81	90	96	81
0.29	69	71	78	80	89	93	80
0.29	70	74	81	81	92	98	83
0.3	41	41	44	46	51	54	46
0.3	66	70	77	77	88	92	78
0.3	66	68	75	74	84	88	76
0.31	64	66	72	73	81	86	74
0.31	62	64	71	72	81	85	73
0.31	65	68	74	74	84	88	76
0.32	62	64	70	71	78	82	71
0.32	63	66	72	73	82	85	74
0.32	61	65	71	71	80	84	72

TABLE XIX: EFFECT OF SENSOR STAND-OFF DISTANCE ON OSEE III RESPONSE OF D6AC STEEL, SENSOR #4

0.33	73	79	87	85	93	94	85
0.33	64	72	82	84	92	92	81
0.33	66	69	78	79	88	90	78
0.34	55	58	65	63	70	70	64
0.34	62	67	71	71	78	76	71
0.34	55	58	65	68	75	78	66
0.35	49	52	59	61	70	71	60
0.35	57	58	64	65	73	68	64
0.35	56	60	68	68	76	77	68
0.36	55	58	64	64	70	70	63
0.36	45	47	54	57	63	65	55
0.36	51	55	60	61	68	68	60
0.37	48	50	56	57	66	66	57
0.37	53	56	63	62	70	65	61
0.37	44	48	55	57	63	61	55
0.38	49	50	56	58	64	65	57
0.38	45	47	54	55	60	62	54
0.38	35	36	41	42	46	48	41
0.39	33	33	37	40	47	50	40
0.39	36	37	42	45	51	48	43
0.39	49	48	55	54	60	61	54
0.4	34	36	42	44	49	53	43
0.4	35	36	39	41	44	43	40
0.4	34	38	45	48	52	56	45

Stand-off distance is inches between sensor and substrate, results are in counts.
Scan rate 2, 0 second delay time, continuous scanning mode.
A passivated D6AC steel panel was used for the tests. The panel measured 480 cV on the OSEE II.
AC64n/7/95

TABLE XX: OSEE III ANALYSIS OF GRIT BLASTED D6AC STEEL USING CONTINUOUS AND DISCRETE SCANNING MODES, SENSOR #4

TIME, MINUTES	COUNTS, CONTINUOUS MODE	TIME, MINUTES	COUNTS, DISCRETE MODE
0	346	3	330
5	313	7	306
9	300	10	289
12	287	14	281
15	284	17	271
19	277	21	272
23	271	24	257
26	256	28	261
30	258	32	256
34	256	36	252
38	254	39	243
41	244	43	243
45	238	47	232
49	242	51	239
53	245	54	227
56	231	58	229
60	230	62	229
68	223	70	218
80	214	82	210
100	199	102	195
110	206	113	204
120	195	122	208
130	208	132	200
150	193	152	183
170	179	172	184
188	185	190	188
268	154	270	166
330	181	332	184

Panel was grit blasted at 20 degrees.
Sensor stand-off distance 1/4", 0 second delay time, scan speed 2, OSEE III sensor #4.
AC65H/8/95

TABLE XXI: OSEE III ANALYSIS OF GRIT BLASTED D6AC STEEL WITH SCAN SPEEDS FROM 1-4 INCHES/SECOND, SENSOR #4

MINUTES	COUNTS, SPD 1	MINUTES	COUNTS, SPD. 2	MINUTES	COUNTS, SPD. 3	MINUTES	COUNTS, SPD. 4
0	208	1	213	3	206	4	205
6	207	8	202	9	204	11	199
16	200	18	203	20	200	22	188
24	205	26	196	28	200	29	195
31	191	32	197	34	198	36	196
37	199	39	195	40	192	42	196
43	194	45	195	47	187	48	188
50	186	51	189	52	189	54	194
56	187	58	190	59	191	60	186
75	186	78	186	81	188	87	182
90	195	92	181	94	184	95	194
105	184	107	190	109	186	110	190
120	189	122	187	124	187	126	188
135	179	137	181	138	183	140	181
150	174	151	181	153	182	155	172
300	142	301	149	303	148	305	147
330	140	332	141	334	142	335	141
400	177	402	182	404	174	406	164

Scan speeds are inches/second.
Panel was grit blasted at 20 degrees.
Sensor stand-off distance 1/4", 0 second delay, continuous scanning mode, sensor #4.
AC65J/8/95

TABLE XXII: EFFECT OF SENSOR DWELL TIME ON OSEE III RESPONSE OF GRIT BLASTED D6AC STEEL, SENSOR #4

MINUTES	DWELL TIME	CH 1	CH 2	CH 3	CH 4	CH 5	CH 6	AVG. COUNTS
0	0	205	230	240	246	246	230	233
3	5	225	243	234	232	227	215	230
4	10	226	232	221	220	221	211	222
5	0	221	227	218	222	227	218	222
6	5	218	222	211	213	216	206	214
7	10	214	221	212	211	212	201	212
10	0	200	207	199	203	208	197	202
11	5	204	210	201	200	202	191	201
13	10	210	217	209	207	209	199	209
20	0	200	203	190	189	188	176	191
21	5	203	209	197	197	200	190	199
22	10	208	214	202	201	205	196	204
30	0	190	197	186	190	197	186	191
31	5	197	204	195	194	195	183	195
32	10	201	207	197	194	195	184	196
45	0	181	187	178	180	185	177	181
46	5	185	190	180	183	185	176	183
47	10	185	192	185	188	190	180	187
55	0	181	187	179	182	186	176	182
56	5	183	192	184	188	186	179	185
57	10	184	188	181	183	183	175	182
60	0	180	186	178	182	186	178	181
61	5	180	185	179	181	183	177	181
62	10	167	171	166	166	166	162	166
70	0	169	177	170	175	178	171	173
71	5	176	185	180	182	182	174	180
72	10	179	185	177	177	178	173	178
80	0	150	155	150	154	159	154	154
81	5	154	159	155	159	162	157	157
82	10	175	178	170	168	169	165	171
160	0	192	197	186	191	195	185	191
161	5	191	195	183	189	189	181	188
162	10	196	200	187	191	194	188	193
180	0	199	204	191	202	209	196	200
181	5	200	208	195	202	204	194	200
182	10	203	209	198	204	206	195	202
200	0	188	193	181	187	190	181	187
201	5	183	185	172	179	181	174	179
202	10	190	193	181	188	190	183	188
220	0	186	193	181	189	192	184	187
221	5	183	188	178	185	187	179	183
222	10	185	190	180	187	189	182	186

TABLE XXII: EFFECT OF SENSOR DWELL TIME ON OSEE III RESPONSE OF GRIT BLASTED D6AC STEEL, SENSOR #4

250	0	198	207	196	206	213	206	204
251	5	199	204	193	203	206	199	201
252	10	199	204	194	202	207	200	201
280	0	186	192	181	191	196	189	189
281	5	189	198	188	193	196	193	193
282	10	183	190	183	192	193	187	188
340	0	147	150	141	149	153	149	148
341	5	150	153	146	152	154	151	151
342	10	151	153	146	153	155	151	152

Grit blast angle 20 degrees.
OSEE III sensor stand-off distance 1/4", scan speed 2, continuous scanning mode.
AC65L/8/95

TABLE XXIII: EFFECT OF SENSOR DWELL TIME ON OSEE III RESPONSE OF GRIT BLASTED D6AC STEEL, 6" SENSOR #4

Scan Distance Centimeters	0 Time 0 Sec. Delay	0 Time 5 Sec. Delay	0 Time 10 Sec. Delay	5 Hours 0 Sec. Delay	5 Hours 5 Sec. Delay	5 Hours 10 Sec. Delay
0.0	126	196	193	118	158	147
0.2	133	181	195	129	143	155
0.4	150	180	196	133	143	148
0.5	145	183	197	134	142	145
0.7	151	193	218	138	155	140
0.9	152	192	204	132	138	149
1.1	152	196	208	132	134	134
1.2	157	213	207	131	147	132
1.4	180	206	204	131	131	129
1.6	185	210	210	147	130	126
1.8	198	214	208	131	125	125
1.9	207	212	209	130	126	122
2.1	215	211	215	133	126	125
2.3	222	227	214	131	127	122
2.5	227	214	211	132	128	124
2.6	234	218	212	134	129	127
2.8	238	222	213	132	126	126
3.0	237	222	216	130	128	125
3.2	241	225	219	134	128	127
3.3	242	220	219	134	129	128
3.5	249	230	218	149	129	142
3.7	247	228	213	133	129	128
3.9	264	227	214	132	131	126
4.0	252	232	226	138	132	127
4.2	261	230	216	146	128	130
4.4	280	235	215	133	131	131
4.6	265	237	230	132	130	131
4.7	271	239	215	133	134	151
4.9	259	241	219	151	136	137

Grit blast angle 20 degrees, sensor stand-off distance 1/4", continuous scanning mode, scan speed 2.

AC65N/8/95

TABLE XXIII: EFFECT OF SENSOR DWELL TIME ON OSEE III RESPONSE OF GRIT BLASTED D6AC STEEL, 6" SENSOR #4

5.1	269	245	232	138	138	140
5.3	249	243	222	137	139	144
5.4	246	244	216	153	143	155
5.6	234	244	215	143	147	149
5.8	229	246	218	147	148	150
6.0	228	245	228	145	154	168
6.1	221	240	223	147	153	152
6.3	223	240	221	150	155	157
6.5	237	240	225	160	158	158
6.7	228	239	228	154	163	162
6.8	235	239	229	155	164	165
7.0	233	246	231	159	167	185
7.2	251	242	238	160	170	171
7.4	250	250	241	162	173	170
7.5	252	249	242	164	175	174
7.7	271	257	238	168	177	172
7.9	258	261	239	167	178	176
8.1	269	265	244	170	183	178
8.2	268	254	242	170	184	178
8.4	270	253	243	174	186	184
8.6	272	248	245	174	186	188
8.8	270	241	241	175	184	187
8.9	286	252	247	178	188	184
9.1	281	232	258	181	204	186
9.3	282	231	247	180	186	186
9.5	290	232		180	187	187
9.6	291	244		181	194	187
9.8		230		184		188

Grit blast angle 20 degrees, sensor stand-off distance 1/4", continuous scanning mode, scan speed 2.

AC65N/8/95

TABLE XXIV: EFFECT OF HD-2 GREASE CONTAMINATION ON OSEE II AND OSEE III RESPONSES OF D6AC STEEL

HD-2 LEVEL, MG/FT2	OSEE III RESPONSE, COUNTS	% ORIGINAL SIGNAL	OSEE II RESPONSE, cV	% ORIGINAL SIGNAL
0	214	100	850	100
0.5	NA	NA	765	90
1	181	85	689	81
2	145	68	570	67
3	128	60	527	62
4	126	59	493	58
5	103	48	476	56
6	98	46	468	55
7	81	38	451	53
8	81	38	442	52
9	67	31	425	50
10	70	33	400	47
15	47	22	NA	NA
20	63	29	323	38
25	46	21	306	36
50	47	22	247	29
100	52	24	NA	NA
155	59	28	NA	NA

Stand-off distances for OSEE II and OSEE III were 1/4". OSEE III analyses performed at scan speed 2, continuous scanning mode, and 0 second dwell time. OSEE III sensor #4 was used for the tests.

AC650/8/95

TABLE XXV: EFFECT OF GRIT BLAST ANGLE ON OSEE III RESPONSE OF D6AC STEEL, 6" SENSOR #4

Time After Grit Blast	20 Degree Blast Angle	45 Degree Blast Angle	90 Degree Blast Angle
0 min.	195	154	129
10 min.	169	144	117
20 min.	167	137	114
30 min.	168	133	110
40 min.	166	127	107
50 min.	158	127	103
60 min.	168	125	104
80 min.	164	121	106
100 min.	163	121	106
120 min.	156	114	102
150 min.	151	108	106
180 min.	145	103	104
210 min.	145	110	106
240 min.	144	108	104
270 min.	139	103	103
300 min.	137	101	101
360 min.	NA	97	98
1 day	NA	132	120
2 days	NA	149	102
3 days	166	137	120
4 days	126	NA	116
5 days	144	NA	NA
6 days	145	NA	NA
7 days	151	145	120
8 days	NA	132	112
9 days	NA	122	105
10 days	154	134	118
11 days	145	109	108
12 days	130	NA	NA
13 days	143	NA	NA
14 days	NA	132	123

Sensor stand-off distance 1/4", scan speed 2, 0-second dwell time, continuous scanning mode.
AC67i/9/95

TABLE XXVI: EFFECT OF ARGON GAS PURGE ON OSEE III RESPONSE OF GRIT BLASTED D6AC STEEL, 6" SENSOR #4

Trial Number	Minutes After Grit Blast	Response With Argon Purge	% Signal Drop From Initial	Response Without Argon Purge	% Signal Drop From Initial
1	0	195	NA	107	NA
	10	169	13	94	12
	20	167	14	86	20
	30	168	14	82	23
	40	166	15	NA	NA
	50	158	19	71	34
	60	168	14	71	34
	80	164	16	70	35
	100	163	16	70	35
	120	156	20	67	37
	150	151	23	60	44
	180	145	26	56	48
	210	145	26	54	50
	240	144	26	52	51
	270	139	29	50	53
	300	137	30	50	53
	330	NA	NA	51	52
	360	NA	NA	47	57
	390	NA	NA	45	58
	420	NA	NA	45	58
	450	NA	NA	43	60
	480	NA	NA	41	62
2	0	226	NA	99	NA
	10	209	8	86	13
	20	198	13	80	19
	30	197	13	78	21
	40	187	17	75	24
	50	190	16	74	25
	60	186	18	68	31
	80	183	19	70	29
	100	182	19	71	28
	120	182	19	68	31
	150	177	22	66	33
	180	175	23	66	33
	210	168	26	66	33
	240	157	31	66	33
	270	169	26	65	34
	300	160	29	67	32
	330	149	34	64	35
	360	153	32	62	37
	390	144	36	61	38

Trial #1 used 2 D6AC panels grit blasted at 20 degrees; one was scanned with argon purge, the other was scanned without argon purge. Trial #2 used 1 grit blasted panel which was alternately scanned with and without argon purging. Ac67o/9/95

TABLE XXVII: SUMMARY OF D6AC STEEL ANALYSIS RESULTS WITH OSEE III 6" SENSOR #4

Trial #	Time	Chan1	Chan2	Chan3	Chan4	Chan5	Chan6	Average C1-C6
6	0 Min	281	299	284	287	281	265	283
7		253	264	252	257	265	257	258
8		219	227	216	221	231	209	221
9		263	276	268	269	276	269	270
10		263	281	273	270	272	269	271
11		263	276	268	269	276	267	270
12		249	270	264	266	278	269	266
13		335	350	341	342	361	349	346
14		197	207	206	202	218	217	208
15		205	230	240	246	246	230	233
16		299	324	309	321	335	319	318
17		269	273	254	269	276	258	267
18		183	193	193	193	206	203	195
Average		252	267	259	262	271	260	**262**
Std. Dev.								**42**
7	10 Min.	230	243	230	230	234	229	233
8		195	203	191	193	203	184	195
9		239	252	244	246	251	245	246
10		218	223	218	218	224	222	221
11		239	252	244	246	251	245	246
12		200	211	204	207	218	213	209
13		279	290	283	285	301	296	289
14		189	198	196	193	209	207	199
15		200	207	199	203	208	197	202
16		250	266	255	262	277	264	262
17		205	211	200	206	214	200	206
18		162	169	168	166	176	174	169
Average		217	227	219	221	231	223	**223**
St. Dev.								**33**
6	20 Min.	219	225	209	213	213	209	214
7		210	219	208	209	214	207	211
8		189	195	181	185	192	174	186
9		227	240	231	235	241	234	235
10		206	215	208	210	215	213	211
11		227	240	231	235	241	234	235
12		192	204	198	202	211	205	202
13		270	278	271	273	291	281	277
14		190	200	197	193	209	208	200
15		200	203	190	189	188	176	191
16		227	244	234	241	256	247	242
17		180	186	177	182	194	183	184
18		159	166	166	163	174	175	167
Average		207	217	208	210	218	211	**212**

TABLE XXVII: SUMMARY OF D6AC STEEL ANALYSIS RESULTS WITH OSEE III 6" SENSOR #4

St. Dev.								**29**
6	30 Min.	220	225	209	211	211	205	214
7		200	209	200	205	207	199	203
8		183	187	174	173	181	163	177
9		214	228	223	230	233	228	226
10		196	205	197	198	206	206	201
11		214	228	223	230	233	228	226
12		181	190	185	188	198	193	189
13		247	257	250	254	273	267	258
14		179	187	186	184	203	204	191
15		190	197	186	190	197	186	191
16		228	244	233	240	254	244	240
17		174	183	178	182	195	184	183
18		158	166	169	166	176	174	168
Average		199	208	201	204	213	206	**205**
St. Dev.								**26**
6	40 Min.	219	224	208	211	210	205	213
7		196	204	195	198	202	195	198
8		183	185	175	177	184	169	179
9		208	224	215	224	221	213	218
10		183	188	181	186	191	190	186
11		208	224	215	224	221	213	218
12		174	181	176	180	191	187	182
13		235	244	234	237	256	250	243
14		184	193	192	189	204	204	194
15		181	187	178	180	185	177	181
16		213	224	211	219	207	211	215
17		169	178	171	175	187	177	176
18		158	165	165	164	174	173	166
Average		193	202	194	197	203	197	**198**
St. Dev.								**22**
6	50 Min.	219	225	208	210	210	205	213
7		202	211	199	203	206	197	203
8		176	182	172	176	182	165	176
9		207	216	207	213	217	211	212
10		189	199	193	198	206	202	198
11		207	216	207	213	217	211	212
12		174	181	175	180	190	186	181
13		235	240	232	233	251	241	239
14		177	184	181	180	196	197	186
15		181	187	179	182	186	176	182
16		209	225	215	220	233	222	220
17		163	171	167	169	182	173	171
18		147	155	155	156	168	166	158

TABLE XXVII: SUMMARY OF D6AC STEEL ANALYSIS RESULTS WITH OSEE III 6" SENSOR #4

Average		191	199	192	195	203	196	**196**
St. Dev.								**23**
6	60 Min.	208	213	198	200	203	202	204
7		192	201	192	197	200	195	196
8		177	178	167	167	175	158	170
9		205	219	213	219	221	214	215
10		191	198	191	192	196	191	193
11		205	219	213	219	221	214	215
12		165	172	166	171	182	179	173
13		223	228	219	224	244	240	230
14		178	185	185	182	197	194	187
15		180	186	177	181	186	178	181
16		205	219	209	214	223	216	214
17		163	172	167	171	185	175	172
18		158	166	166	166	177	175	168
Average		188	197	189	193	201	195	**194**
St. Dev.								**21**
6	80 Min.	225	230	211	212	212	207	216
7		188	195	183	188	191	184	188
8		174	179	168	168	177	158	171
9		205	219	210	213	219	214	213
10		174	181	175	181	189	188	181
11		205	219	210	213	219	214	213
12		158	164	159	166	175	171	167
13		208	212	206	209	227	222	214
14		175	183	182	180	198	197	186
15		150	155	150	154	159	154	154
16		197	212	202	208	217	210	208
17		157	165	162	166	180	172	167
18		153	160	159	160	175	174	164
Average		182	190	183	186	195	190	**188**
St. Dev.								**22**
6	100 Min.	229	238	221	222	222	215	224
7		194	201	189	192	196	187	193
8		180	185	172	175	181	159	175
9		200	211	204	207	214	206	207
10		181	192	186	192	198	195	191
11		200	211	204	207	214	206	207
12		162	172	165	171	181	177	171
13		192	196	190	194	211	208	199
14		172	180	180	179	198	197	184
16		202	215	204	210	222	211	211
17		147	155	153	159	172	166	158
18		154	160	159	159	172	171	163

TABLE XXVII: SUMMARY OF D6AC STEEL ANALYSIS RESULTS WITH OSEE III 6" SENSOR #4

Average		184	193	186	189	198	192	**190**
St. Dev.								**21**
6	120 Min.	211	215	197	200	199	192	202
7		190	198	185	187	192	185	189
8		181	187	174	176	184	164	178
9		192	201	195	204	209	203	201
10		192	201	195	204	209	203	201
11		158	166	159	163	174	172	165
13		191	193	186	190	207	204	195
14		180	189	186	182	199	200	189
16		190	200	190	196	207	198	197
17		151	157	153	159	172	165	159
18		149	155	152	153	164	162	156
Average		180	187	179	183	192	186	**185**
St.Dev.								**17**
9	1 Day	176	183	177	181	180	170	178
10		142	147	139	141	143	138	142
Average		159	165	158	161	162	154	**160**
St. Dev.								**25**
9	2 Days	180	191	186	191	194	184	188
11		176	183	177	181	180	180	178
12		130	134	130	132	135	132	132
13		150	153	144	153	160	150	152
Average		159	165	159	164	167	162	**163**
St. Dev.								**25**
9	3 Days	137	145	139	143	144	134	140
11		180	191	186	191	194	182	188
13		172	180	173	185	197	182	181
15		154	167	167	168	176	161	166
Average		161	171	166	172	178	165	**169**
St. Dev.								**21**
11	4 Days	137	145	139	143	144	134	140
13		153	159	153	161	166	150	157
14		157	159	153	157	166	156	158
15		119	126	126	125	134	128	126
Average		142	147	143	147	153	142	**145**
St. Dev.								**15**
10	5 Days	138	147	142	146	148	143	144
12		190	207	204	209	216	205	205
14		199	212	207	211	219	203	209
15		136	144	145	143	153	140	144
Average		166	178	175	177	184	173	**176**
St. Dev.								**36**
10	6 Days	123	128	125	127	127	121	130

TABLE XXVII: SUMMARY OF D6AC STEEL ANALYSIS RESULTS WITH OSEE III 6" SENSOR #4

12		151	158	153	156	158	149	154
14		157	166	163	170	175	159	165
15		137	148	149	146	150	143	145
Average		142	150	148	150	153	143	**149**
St. Dev.								**15**
9	7 Days	135	145	141	144	145	134	141
10		154	163	158	162	167	160	161
12		187	199	194	202	214	195	199
13		132	139	134	139	142	130	136
14		173	184	181	191	201	185	186
15		139	149	152	153	161	152	151
Average		153	163	160	165	172	159	**162**
St. Dev.								**25**
9	8 Days	120	128	127	129	128	118	125
10		118	124	121	124	125	117	122
11		136	145	141	144	145	134	141
12		145	156	152	152	156	152	152
13		133	141	135	145	149	136	140
14		155	164	162	168	173	155	163
Average		135	143	140	144	146	135	**141**
St. Dev.								**16**
9	9 Days	133	143	141	145	149	139	142
11		120	128	127	129	128	118	125
12		133	137	131	131	135	130	133
13		127	133	127	134	139	126	131
Average		128	135	132	135	138	128	**133**
St.Dev.								**7**
9	10 Days	107	113	110	110	113	107	110
11		133	142	141	145	149	139	142
13		125	133	128	139	144	130	133
15		136	151	155	158	169	153	
Average		125	135	134	138	144	132	**135**
St. Dev.								**19**
10	11 Days	112	119	118	120	123	118	118
11		107	113	110	110	113	107	110
13		109	116	110	119	122	112	115
14		135	144	143	148	151	138	143
15		136	147	148	147	153	141	145
Average		120	128	126	129	132	123	**126**
St. Dev.								**17**
10	12 Days	109	118	115	115	115	109	114
12		160	174	171	175	177	170	171
14		134	145	142	151	155	142	145
15		126	135	134	134	135	119	130

TABLE XXVII: SUMMARY OF D6AC STEEL ANALYSIS RESULTS WITH OSEE III 6" SENSOR #4

Average		132	143	141	144	146	135	**140**
St. Dev.								**24**
9	13 Days	120	131	130	130	131	122	127
10		142	153	150	155	156	147	151
12		149	158	153	159	159	149	155
14		133	142	141	146	151	136	142
15		132	142	144	145	152	139	143
Average		135	145	144	147	150	139	**144**
St. Dev.								**11**
9	14 Days	102	108	106	106	107	100	105
10		101	106	103	106	108	102	104
11		120	131	130	130	131	122	127
12		115	128	121	121	123	114	120
14		132	144	141	150	157	141	144
Average		114	123	120	123	125	116	**120**
St.Dev.								**17**

Grit blast angle 20 degrees, stand-off distance 1/4", continuous scanning mode, scan speed 2.
Average conditions during analyses were 75F, 45% RH.
AC68J/10/95

APPENDIX A

Statistical Analysis Results From LiAl Environmental Studies

D E S I G N - E X P E R T   A N A L Y S I S

===

Response: Slope; File = LIALB   Run on 10/06/95 at 07:49:21

===

FAC	FACTOR	UNITS	-1 LEVEL	+1 LEVEL
A	Temperature	Degrees F	58.000	88.000
B	RH	Percent	22.000	66.000

***** WARNING: The Cubic Model is Aliased! *****

Sequential Model Sum of Squares

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	PROB > F
MEAN	0.0097614	1	0.0097614		
Linear	0.0002170	2	0.0001085	1.04	0.410
Quadratic	0.0004395	3	0.0001465	2.33	0.252
Cubic	0.0000000	0			
RESIDUAL	0.0001883	3	0.0000628		
TOTAL	0.0106061	9			

Model Summary Statistics

SOURCE	ROOT MSE	R-SQR	ADJ R-SQR	PRED R-SQR	PRESS
Linear	0.01023	0.2568	0.0091	-1.0473	0.00173
Quadratic	0.00792	0.7771	0.4056	-3.6847	0.00396
Cubic	0.00792	0.7771			

Case(s) with leverage of 1.0000: PRESS statistic not defined.

===

Response: Slope; File = LIALB   Run on 10/06/95 at 07:49:31

===

FAC	FACTOR	UNITS	-1 LEVEL	+1 LEVEL
A	Temperature	Degrees F	58.000	88.000
B	RH	Percent	22.000	66.000

ANOVA for Linear Model

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	PROB > F
MODEL	0.0002170	2	0.00011	1.04	0.410
RESIDUAL	0.0006277	6	0.00010		
COR TOTAL	0.0008447	8			

ROOT MSE	0.01023	R-SQUARED	0.2568
DEP MEAN	-0.03293	ADJ R-SQUARED	0.0091
		PRED R-SQUARED	-1.0473

Predicted Residual Sum of Squares (PRESS) = 0.0017294

D E S I G N - E X P E R T   A N A L Y S I S -- Page 2

FACTOR	COEFFICIENT ESTIMATE	DF	STD ERROR	t FOR H0 COEF=0	PROB > |t|	VIF
Intercept	-0.03244	1	0.00343	-9.45		
A-Temperature	0.00266	1	0.00423	0.63	0.553	1.00
B-RH	-0.00631	1	0.00498	-1.27	0.252	1.00

Final Equation in Terms of Coded Factors:

$$\text{Slope} = -0.03244 + 0.00266 * A - 0.00631 * B$$

Final Equation in Terms of Actual Factors:

$$\text{Slope} = -0.03276 + 1.772E-04 * \text{Temperature} - 2.868E-04 * \text{RH}$$

Obs Ord	ACTUAL VALUE	PREDICTED VALUE	RESIDUAL	LEVER	STUDENT RESID	COOK'S DIST	OUTLIER t	Run Ord
1	-0.04000	-0.02879	-0.01121	0.579	-1.69	1.312	-2.13	1
2	-0.01880	-0.03653	0.01773	0.287	2.05	0.565	3.44	2
3	-0.04440	-0.04123	-0.00317	0.447	-0.42	0.047	-0.39	3
4	-0.02800	-0.02900	0.00100	0.204	0.11	0.001	0.10	4
5	-0.03000	-0.03330	0.00330	0.112	0.34	0.005	0.32	5
6	-0.04970	-0.03847	-0.01123	0.292	-1.31	0.234	-1.41	6
7	-0.02100	-0.02491	0.00391	0.437	0.51	0.067	0.48	7
8	-0.03400	-0.03036	-0.00364	0.279	-0.42	0.023	-0.39	8
9	-0.03050	-0.03380	0.00330	0.362	0.40	0.031	0.37	9

==
Response: Y-Intercept; File = LIALB   Run on 10/06/95 at 07:55:53
==

FAC	FACTOR	UNITS	-1 LEVEL	+1 LEVEL
A	Temperature	Degrees F	58.000	88.000
B	RH	Percent	22.000	66.000

***** WARNING: The Cubic Model is Aliased! *****

Sequential Model Sum of Squares

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	PROB > F

Linear	98953.3	2	49476.6	2.00	0.216
Quadratic	49384.4	3	16461.5	0.50	0.709
Cubic	0.0	0			
RESIDUAL	99247.3	3	33082.4		
TOTAL	22803752.0	9			

D E S I G N - E X P E R T   A N A L Y S I S -- Page 3

Model Summary Statistics

SOURCE	ROOT MSE	R-SQR	ADJ R-SQR	PRED R-SQR	PRESS
Linear	157.4	0.3997	0.1996	-0.3672	338506.2
Quadratic	181.9	0.5991	-0.0690	-7.1863	2026807.8
Cubic	181.9	0.5991			

Case(s) with leverage of 1.0000: PRESS statistic not defined.

Response: Y-Intercept; File = LIALB   Run on 10/06/95 at 07:55:59

FAC	FACTOR	UNITS	-1 LEVEL	+1 LEVEL
A	Temperature	Degrees F	58.000	88.000
B	RH	Percent	22.000	66.000

ANOVA for Linear Model

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	PROB > F
MODEL	98953.3	2	49476.6	2.00	0.216
RESIDUAL	148631.6	6	24771.9		
COR TOTAL	247584.9	8			

ROOT MSE	157.4	R-SQUARED	0.3997
DEP MEAN	1583.1	ADJ R-SQUARED	0.1996
C.V.	9.94%	PRED R-SQUARED	-0.3672

Predicted Residual Sum of Squares (PRESS) = 338506.2

FACTOR	COEFFICIENT ESTIMATE	DF	STD ERROR	t FOR H0 COEF=0	PROB > |t|	VIF
Intercept	1595.3	1	52.8	30.20		
A-Temperature	10.9	1	65.0	0.17	0.872	1.00
B-RH	-151.9	1	76.6	-1.98	0.095	1.00

Final Equation in Terms of Coded Factors:

Y-Intercept =
1595.3
+ 10.9 * A
- 151.9 * B

ORIGINAL PAGE IS OF POOR QUALITY

Final Equation in Terms of Actual Factors:

Y-Intercept = 1845.8
+ 0.72849 * Temperature
- 6.9024 * RH

DESIGN-EXPERT ANALYSIS -- Page 4

Obs Ord	ACTUAL VALUE	PREDICTED VALUE	RESIDUAL	LEVER	STUDENT RESID	COOK'S DIST	OUTLIER t	Run Ord
1	1704.0	1736.2	-32.2	0.579	-0.32	0.046	-0.29	1
2	1392.0	1549.9	-157.9	0.287	-1.19	0.189	-1.24	2
3	1527.0	1433.3	93.7	0.447	0.80	0.173	0.77	3
4	1724.0	1678.1	45.9	0.204	0.33	0.009	0.30	4
5	1639.0	1574.6	64.4	0.112	0.43	0.008	0.40	5
6	1539.0	1450.4	88.6	0.292	0.67	0.062	0.64	6
7	1726.0	1723.6	2.4	0.437	0.02	0.000	0.02	7
8	1757.0	1592.4	164.6	0.279	1.23	0.196	1.30	8
9	1240.0	1509.6	-269.6	0.362	-2.14	0.868	-4.05*	9

* Case(s) with |Outlier T| > 3.50

==

Response: Delta OSEE; File = LIALB Run on 10/06/95 at 08:01:07

==

FAC	FACTOR	UNITS	-1 LEVEL	+1 LEVEL
A	Temperature	Degrees F	58.000	88.000
B	RH	Percent	22.000	66.000

***** WARNING: The Cubic Model is Aliased! *****

Sequential Model Sum of Squares

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	PROB > F
MEAN	1862315.1	1	1862315.1		
Linear	206741.5	2	103370.8	24.28	0.001
Quadratic	22553.7	3	7517.9	7.54	0.066
Cubic	0.0	0			
RESIDUAL	2989.7	3	996.6		
TOTAL	2094600.0	9			

Model Summary Statistics

SOURCE	ROOT MSE	R-SQR	ADJ R-SQR	PRED R-SQR	PRESS
Linear	65.2	0.8900	0.8534	0.6896	72112.2
Quadratic	31.6	0.9871	0.9657	0.7566	56537.6
Cubic	31.6	0.9871			

Case(s) with leverage of 1.0000: PRESS statistic not defined.

==

FAC	FACTOR	UNITS	-1 LEVEL	+1 LEVEL
A	Temperature	Degrees F	58.000	88.000
B	RH	Percent	22.000	66.000

ANOVA for Linear Model

SOURCE	SUM OF SQUARES	DF	MEAN SQUARE	F VALUE	PROB > F
MODEL	206741.5	2	103370.8	24.28	0.001
RESIDUAL	25543.4	6	4257.2		
COR TOTAL	232284.9	8			

ROOT MSE	65.2	R-SQUARED	0.8900
DEP MEAN	454.9	ADJ R-SQUARED	0.8534
C.V.	14.34%	PRED R-SQUARED	0.6896

Predicted Residual Sum of Squares (PRESS) = 72112.2

FACTOR	COEFFICIENT ESTIMATE	DF	STD ERROR	t FOR H0 COEF=0	PROB > |t|	VIF
Intercept	439.9	1	21.9	20.09		
A-Temperature	-84.9	1	27.0	-3.15	0.020	1.00
B-RH	192.9	1	31.8	6.08	< 0.001	1.00

Final Equation in Terms of Coded Factors:

Delta OSEE =

$$439.9 - 84.9 * A + 192.9 * B$$

Final Equation in Terms of Actual Factors:

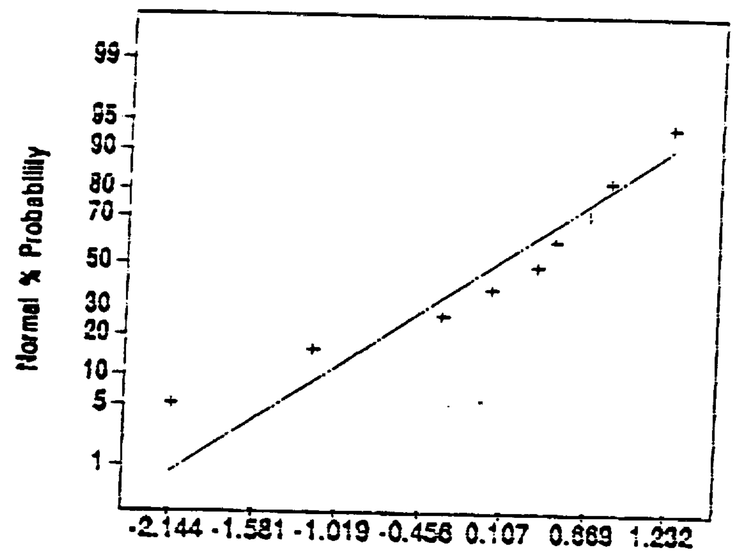
Delta OSEE =

$$467.3 - 5.6613 * \text{Temperature} + 8.7698 * \text{RH}$$

Obs Ord	ACTUAL VALUE	PREDICTED VALUE	RESIDUAL	LEVER	STUDENT RESID	COOK'S DIST	OUTLIER t	Run Ord
1	413.0	331.9	81.1	0.579	1.92	1.687	2.81	1
2	508.0	568.7	-60.7	0.287	-1.10	0.163	-1.13	2
3	735.0	712.1	22.9	0.447	0.47	0.060	0.44	3
4	252.0	334.7	-82.7	0.204	-1.42	0.172	-1.59	4
5	410.0	466.2	-56.2	0.112	-0.91	0.035	-0.90	5
6	678.0	624.1	53.9	0.292	0.98	0.132	0.98	6
7	242.0	205.9	36.1	0.437	0.74	0.141	0.71	7
8	359.0	372.5	-13.5	0.279	-0.24	0.008	-0.22	8
9	497.0	477.8	19.2	0.362	0.37	0.026	0.34	9

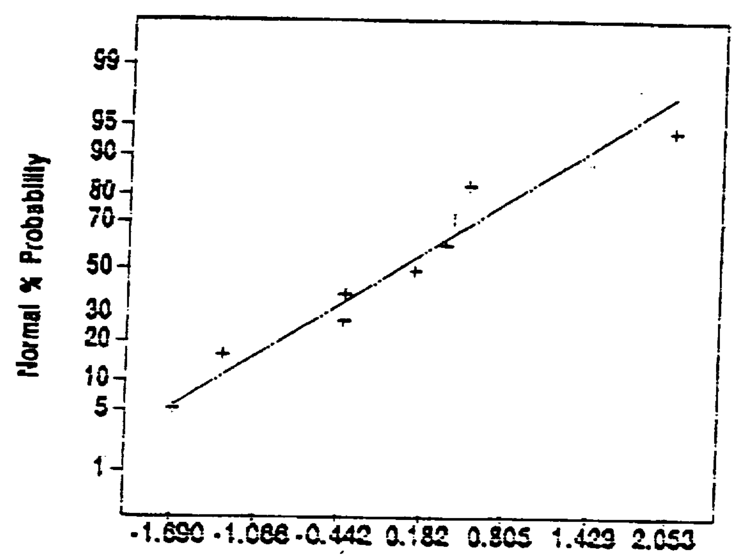
DESIGN-EXPERT Plot
Model:
Linear

Response: Y-intercept



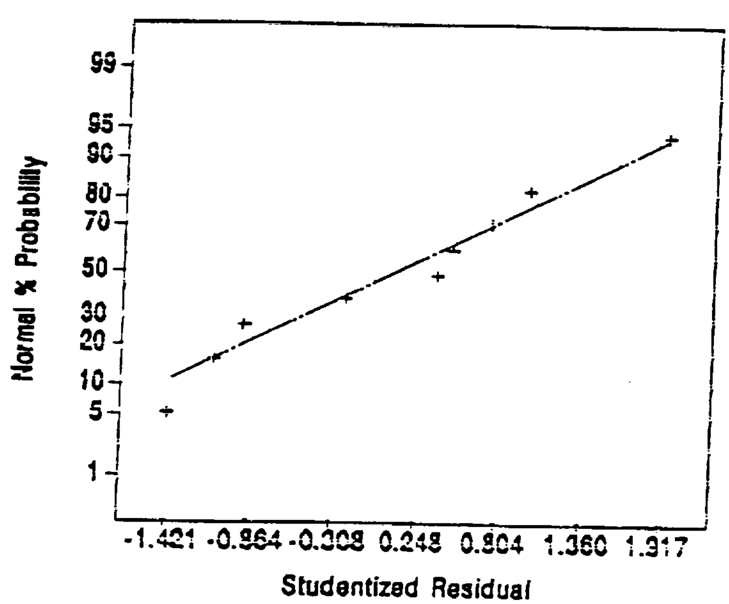
DESIGN-EXPERT Plot
Model:
Linear

Response: Slope



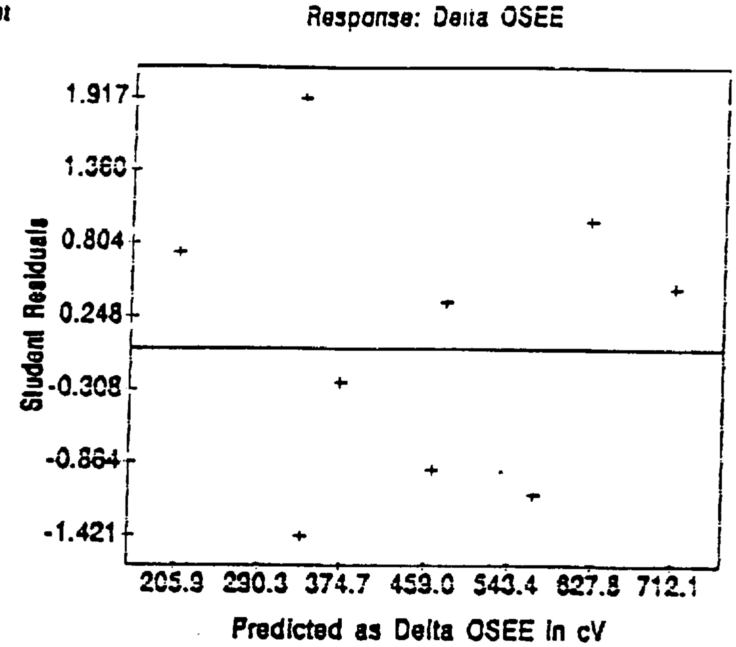
DESIGN-EXPERT Plot
Model:
Linear

Response: Delta OSEE



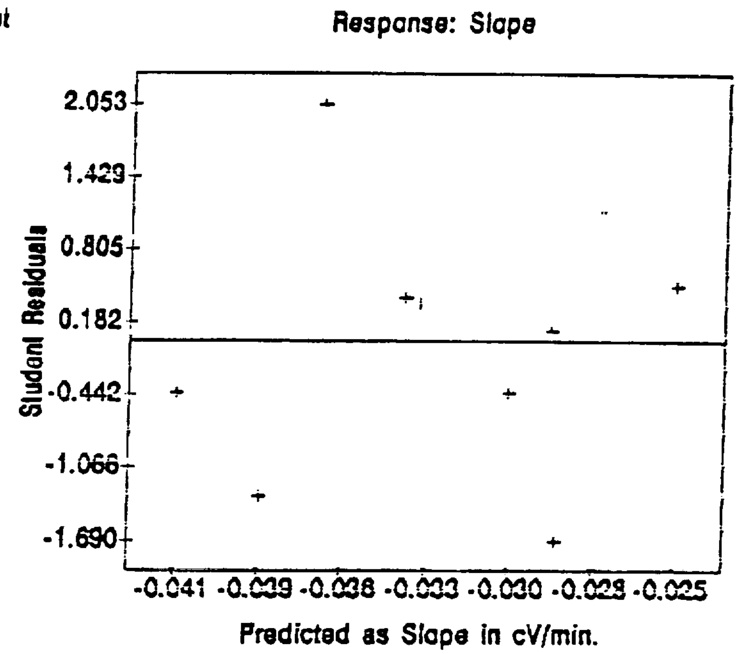
LJAL3.DAT
10/06/96 08:04:03

DESIGN-EXPERT Plot
Model:
Linear



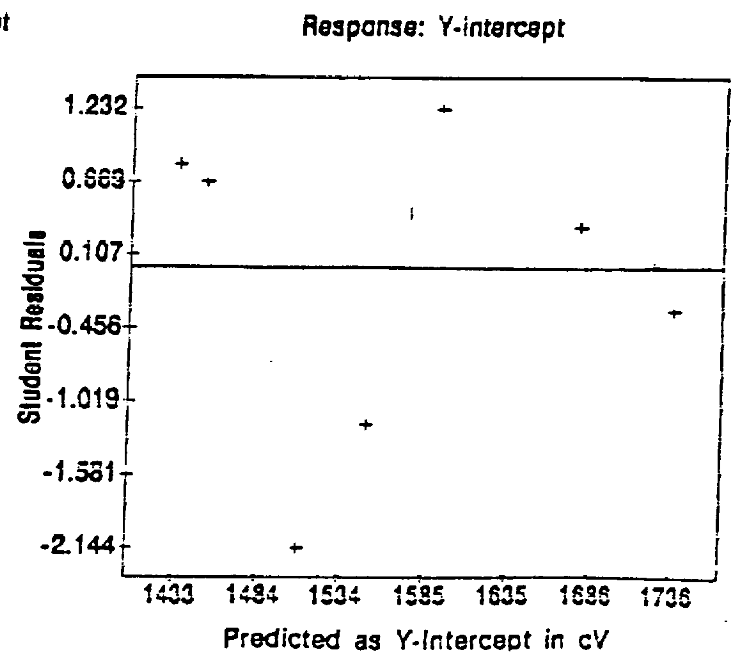
LJAL3.DAT
10/06/96 08:06:41

DESIGN-EXPERT Plot
Model:
Linear

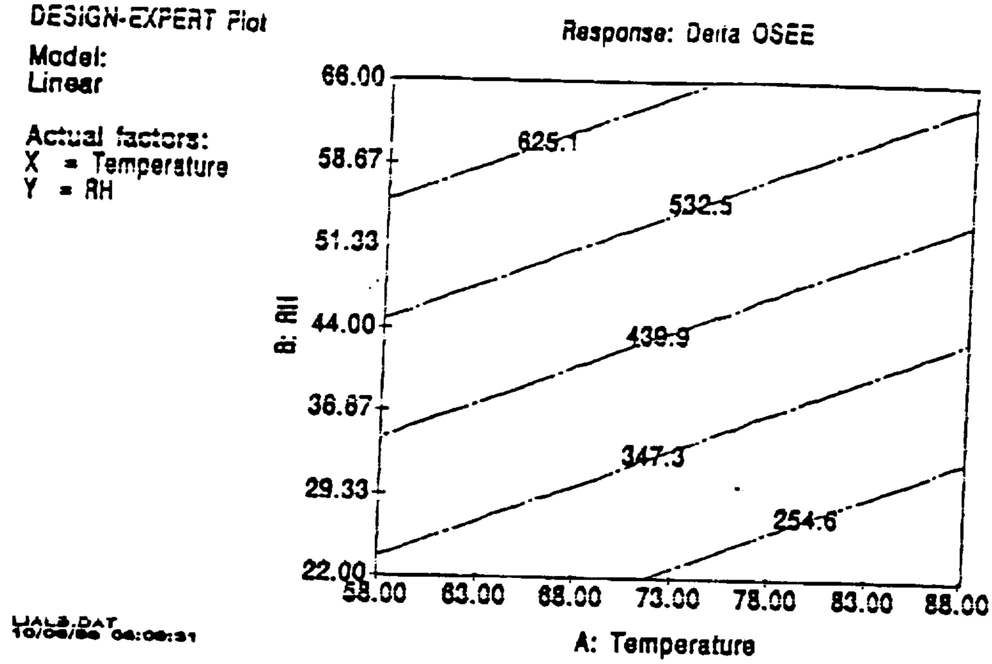


LJAL3.DAT
10/06/96 07:50:37

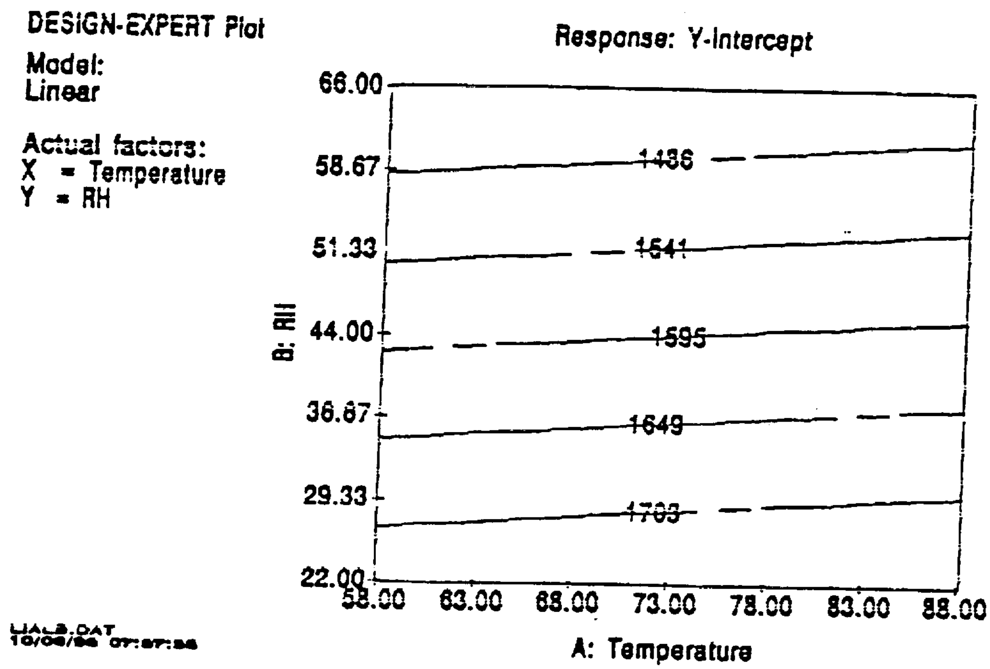
DESIGN-EXPERT Plot
Model:
Linear



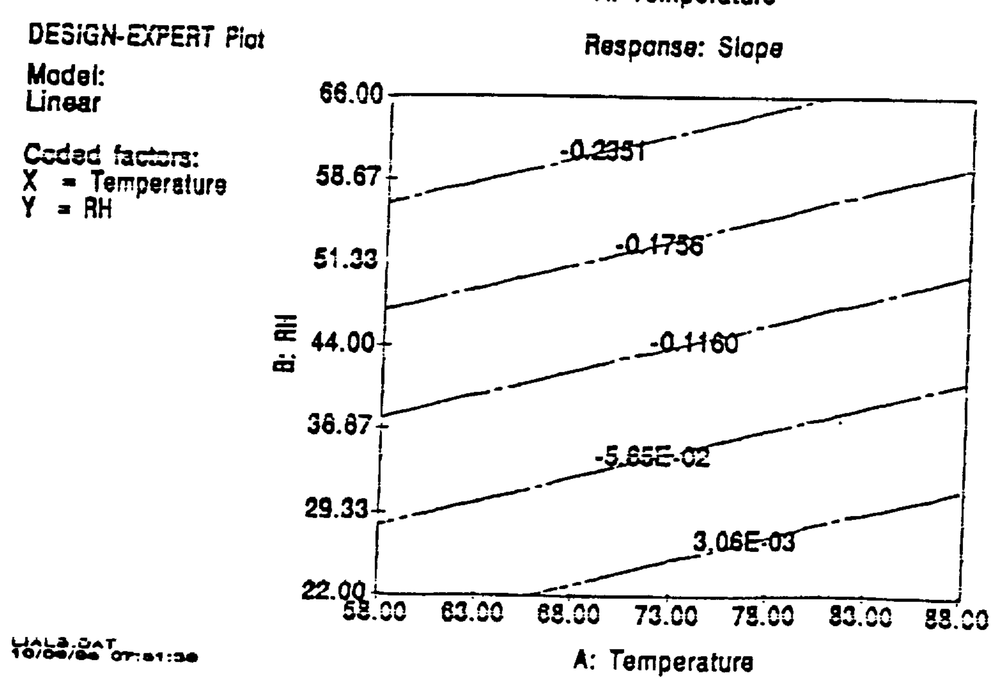
LJAL3.DAT
10/06/96 07:37:12



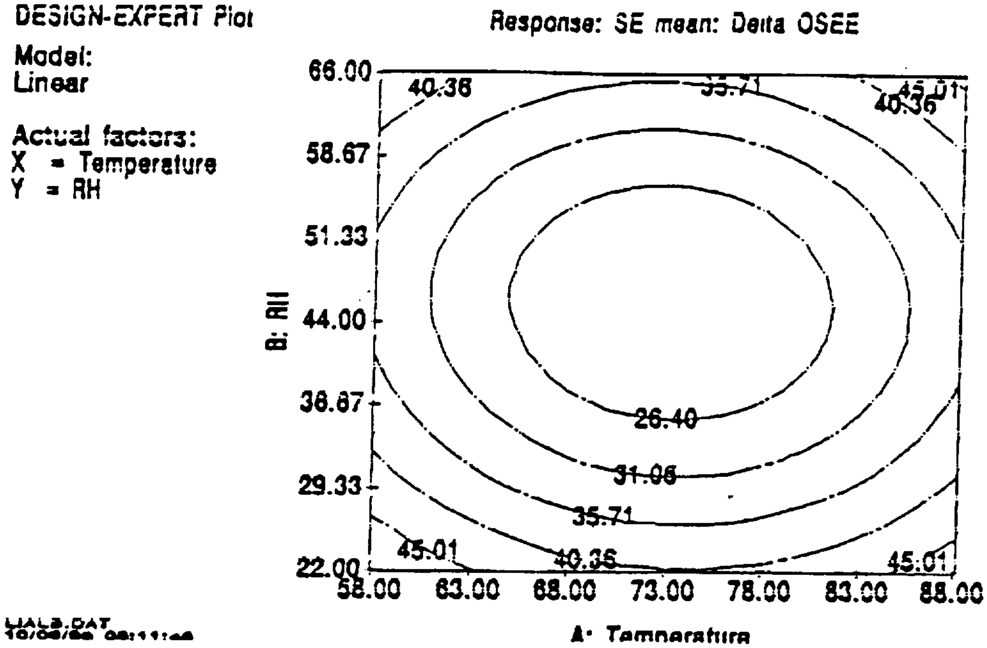
DESIGN-EXPERT Plot
Model:
Linear
Actual factors:
X = Temperature
Y = RH
Response: Delta OSEE
625.1
532.5
439.9
347.3
254.6
66.00
58.67
51.33
44.00
36.67
29.33
22.00
B: RH
58.00
63.00
68.00
73.00
78.00
83.00
88.00
A: Temperature

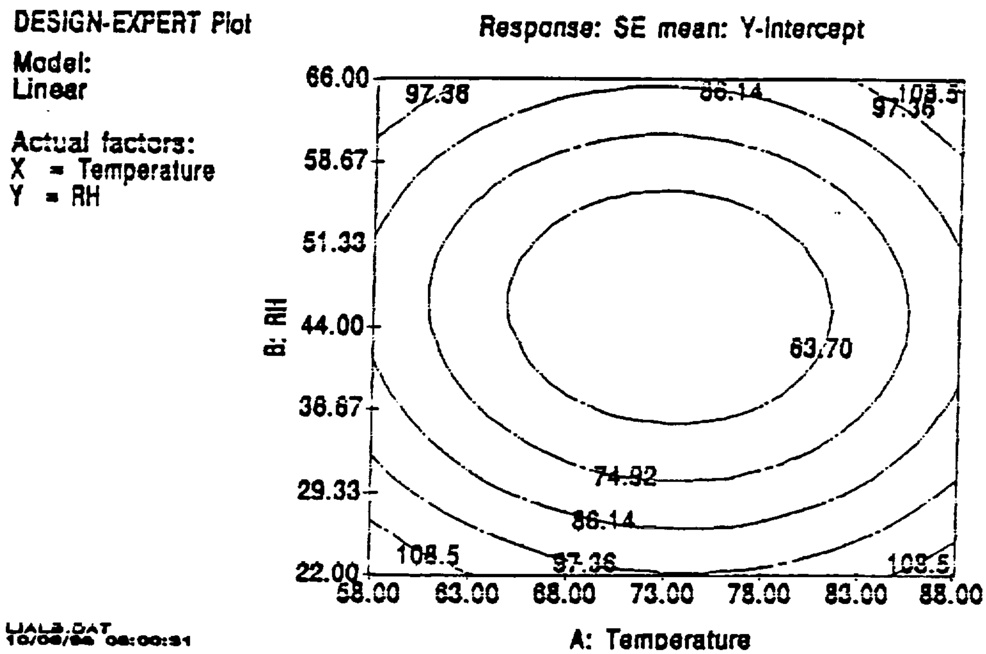


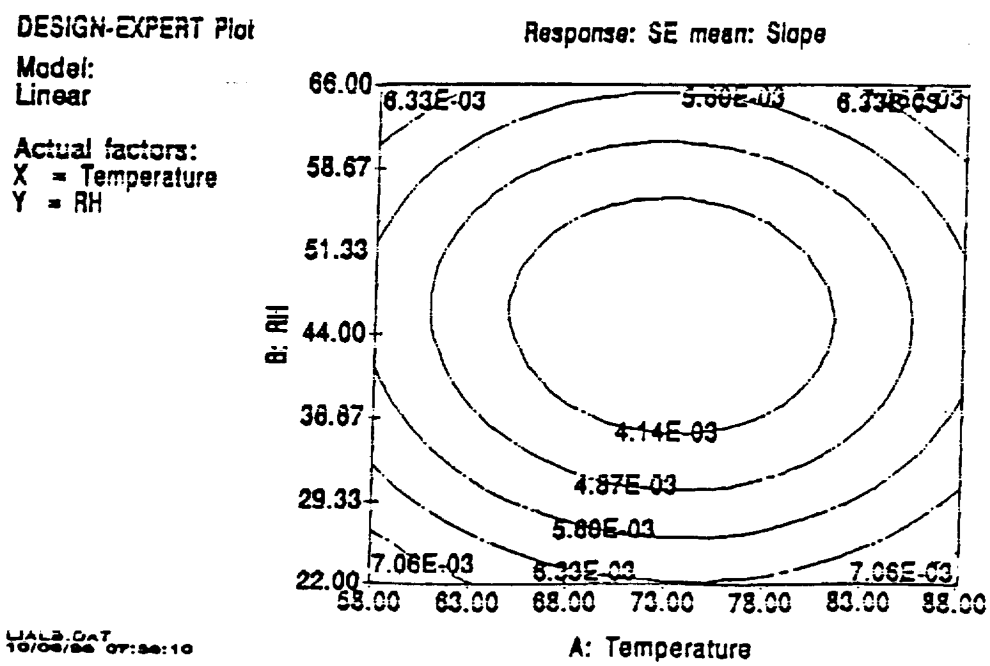
DESIGN-EXPERT Plot
Model:
Linear
Actual factors:
X = Temperature
Y = RH
Response: Y-Intercept
1486
1541
1595
1649
1703
66.00
58.67
51.33
44.00
36.67
29.33
22.00
B: RH
58.00
63.00
68.00
73.00
78.00
83.00
88.00
A: Temperature



DESIGN-EXPERT Plot
Model:
Linear
Coded factors:
X = Temperature
Y = RH
Response: Slope
-0.2351
-0.1756
-0.1160
-5.65E-02
3.06E-03
66.00
58.67
51.33
44.00
36.67
29.33
22.00
B: RH
58.00
63.00
68.00
73.00
78.00
83.00
88.00
A: Temperature


DESIGN-EXPERT Plot
Model:
Linear
Actual factors:
X = Temperature
Y = RH
Response: SE mean: Delta OSEE
40.36
35.71
45.01
40.36
26.40
31.06
35.71
45.01
40.36
45.01
66.00
58.67
51.33
44.00
36.67
29.33
22.00
B: RH
58.00
63.00
68.00
73.00
78.00
83.00
88.00
A: Temperature


DESIGN-EXPERT Plot
Model:
Linear
Actual factors:
X = Temperature
Y = RH
Response: SE mean: Y-Intercept
97.36
86.14
108.5
97.36
63.70
74.92
86.14
108.5
97.36
108.5
66.00
58.67
51.33
44.00
36.67
29.33
22.00
B: RH
58.00
63.00
68.00
73.00
78.00
83.00
88.00
A: Temperature


DESIGN-EXPERT Plot
Model:
Linear
Actual factors:
X = Temperature
Y = RH
Response: SE mean: Slope
6.33E-03
5.60E-03
6.33E-03
4.14E-03
4.87E-03
5.60E-03
7.06E-03
6.33E-03
7.06E-03
66.00
58.67
51.33
44.00
36.67
29.33
22.00
B: RH
58.00
63.00
68.00
73.00
78.00
83.00
88.00
A: Temperature